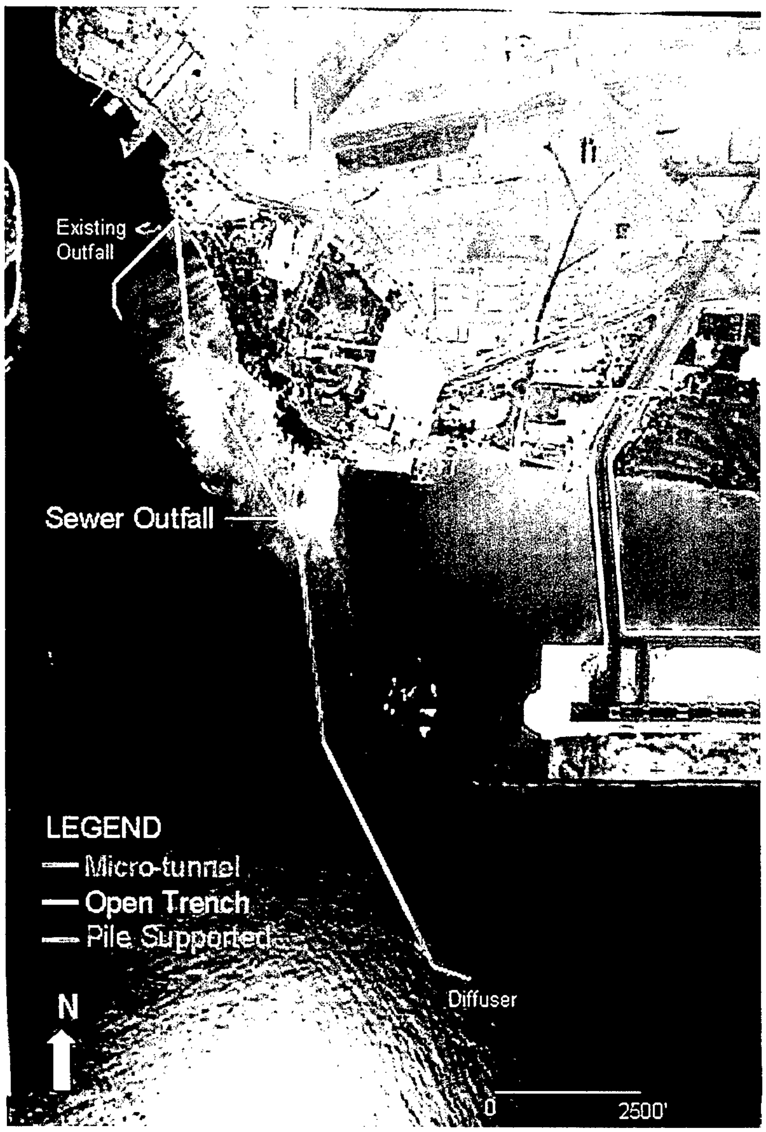
FINAL ENVIRONMENTAL IMPACT STATEMENT

Outfall Replacement for Wastewater Treatment Plant at Fort Kamehameha, Navy Public Works Center, Pearl Harbor, Hawaii



Department of the Navy

March 2001

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
258 MAKALAPA DR., STE. 100
PEARL HARBOR, HI 96860-3134

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From: Commander, Pacific Division, Naval Facilities Engineering Command

Subj: RECORD OF DECISION (ROD) FOR WWTP AT FORT KAMEHAMEHA OUTFALL REPLACEMENT ENVIRONMENTAL IMPACT STATEMENT, NAVY PUBLIC WORKS CENTER, PEARL HARBOR, HAWAII

Encl: (1) Subject ROD of 22 Jun 01

1. Enclosure (1) is forwarded for your information and files.

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DEPARTMENT OF DEFENSE

Department of the Navy

Record of Decision for Outfall Replacement for Wastewater Treatment Plant at Fort Kamehameha, Navy Public Works Center, Pearl Harbor, Hawaii

AGENCY: Department of the Navy, DoD.

ACTION: Notice of Record of Decision.

SUMMARY: The Department of the Navy, after weighing the operational, environmental, and cost implications of alternatives to the existing outfall for the Wastewater Treatment Plant (WWTP) at Fort Kamehameha, Pearl Harbor, Hawaii, announces its decision to construct a deep ocean outfall replacement that will discharge effluent into the open coastal waters of Mamala Bay to the south of the island of Oahu.

FOR FURTHER INFORMATION CONTACT: Mr. Melvin Kaku, Pacific Division Naval Facilities Engineering Command (PLN23), 258 Makalapa Drive, Suite 100, Pearl Harbor, HI 96860-3134, telephone (808) 471-9338, facsimile (808) 474-5909.

SUPPLEMENTAL INFORMATION: The Record of Decision (ROD) in its entirety is provided as follows:

Pursuant to Section 102(2)(c) of the National Environmental Policy Act (NEPA) of 1969, 42 U.S.C. Section 4332(2)(c), and the regulations of the Council on Environmental Quality that implement NEPA procedures, 40 CFR Parts 1500-1508, the Department of the Navy (DON) announces its decision to replace a physically deteriorating effluent outfall that discharges wastewater into the entrance channel of the Pearl Harbor Estuary with a deep ocean outfall into the open coastal waters of Mamala Bay where the effluent loading is less likely to adversely impact the environment.

The existing outfall has been operating under an administrative extension to a National Pollutant Discharge Elimination System (NPDES) monitoring permit that expired on February 28, 1993. The Navy was advised by U.S. Environmental Protection Agency (EPA) Region 9 on January

24, 1997, that a new NPDES permit will limit the discharge of nutrients and metals to levels below those presently permitted. Replacement of the existing outfall will reduce pollutant loadings and water quality deterioration in the Pearl Harbor Estuary, and enable DON to be in compliance. As described in the Final Environmental Impact Statement (FEIS), the DON will construct and operate a new deep ocean outfall. The new outfall will provide an effluent disposal system that meets environmental and other regulatory constraints. All practicable means to avoid or minimize environmental harm from the alternative selected have been adopted.

PROCESS

On September 11, 1996, the DON published in the Federal Register (61 FR 47898) a Notice of Intent to prepare an Environmental Impact Statement (EIS). On September 23, 1996, an EIS Preparation Notice was published in The Environmental Notice, a semi-monthly bulletin of the Hawaii State Department of Health (DOH). DON held two public scoping meetings on October 1 and October 2, 1996, in Honolulu, HI at Washington Intermediate School and Makalapa Elementary School, respectively. The EPA published a Notice of Availability (NOA) for the Draft EIS (DEIS) in the Federal Register on November 21, 1997 (62 FR 62303). An announcement was also placed in the December 8, 1997, issue of The Environmental Notice. DON held a public hearing to receive comments on the DEIS at Radford High School, Honolulu, HI, on December 17, 1997. In addition, DON distributed the DEIS to 124 government agencies, groups, and individuals. DON considered all oral and written comments in preparation of the FEIS. The EPA published a NOA for the FEIS in the Federal Register on May 4, 2001 (66 FR 22551). A NOA was also published in two local newspapers on May 4, May 5, and May 6, 2001. An announcement was also placed in the May 8, 2001, issue of The Environmental Notice.

ALTERNATIVES CONSIDERED

DON initially considered six alternative methods for reducing the discharge of pollutant loadings from the effluent discharge into the Pearl Harbor Estuary. DON developed conceptual designs for the six alternative methods and conducted a preliminary analysis based on the following: (1) purpose and need of the project; (2) 30-year life-cycle costs; and (3) feasibility of implementation including

construction, operation, and maintenance. DON determined that of the six alternative methods, only the deep ocean outfall and the underground injection alternatives were reasonable. These two alternatives and the "no action" alternative were carried forward for further analysis, with the deep ocean outfall alternative being identified as the preferred alternative. The analysis of the deep ocean outfall alternative included an evaluation of the environmental impacts of various alignments and construction methods that included trenching, microtunneling, and pile-supported pipe above the ocean floor.

Based upon this analysis, DON has chosen to construct a deep ocean outfall that will discharge the wastewater into the open coastal waters of Mamala Bay. The "no action" alternative was rejected as it would not enable the Navy to satisfy reasonably foreseeable regulatory requirements. The underground injection alternative was ultimately rejected in favor of the deep ocean outfall alternative because of its higher 30-year life cycle cost, the fair to poor reliability of the technology involved, and uncertain impacts on adjacent water bodies. The deep ocean outfall alternative is the environmentally preferred alternative.

ENVIRONMENTAL IMPACTS

DON analyzed the direct, indirect, and cumulative impacts of each alternative on environmental resources involving land use and airspace; visual resources; socioeconomics; cultural resources; traffic and circulation; air quality; noise; biological resources; hydrological resources; utilities and services; public health and safety; and hazardous materials and waste. The only significant impacts that could result from the construction of the new WWTP outfall are discussed below.

Aquatic Environment

There is potential for significant impacts on the aquatic environment from normal construction activities. DON and its contractor(s) will employ standard Best Management Practices for construction in coastal waters, such as daily inspection of equipment for conditions that could cause spills or leaks; cleaning of equipment prior to deployment in the water; proper location of storage, refueling, and servicing sites; and implementation of adequate spill response, storm weather preparation plans,

and the use of silt curtains to minimize these potential impact.

There is potential for impacts on the marine environment from the expected increase in turbidity and suspended solids in the water during the construction phase. Turbidity from construction in shallow waters, which tend to be relatively calm, will be contained by the use of silt curtains. Strong wave and current actions in the deep water portions of the project area will act to minimize increased turbidity in those areas. Water quality monitoring will be conducted during the construction period to ensure that water quality standards are not exceeded. Pursuant to Section 401 of the Clean Water Act, DON will obtain and comply with the conditions of a Water Quality Certification from the DOH. The proposed action is expected to meet the conditions of the NPDES permit required by the Hawaii DOH.

There is potential for minor impacts on corals from construction activities associated with the replacement outfall. Construction impacts to areas supporting coral growth have been minimized by careful selection of the preferred outfall alignment and construction methodologies. The aggregate coral coverage impacted by the replacement outfall along its entire length is expected to be less than one-fifth of one percent (i.e., < 0.2 percent) of the total coral on the reef flat within the construction area. The corals that would be affected are not unique and are readily found off the southern shore of Oahu at similar depths.

Protected Species and Habitat

There is potential danger from construction activities to marine species listed as endangered or threatened under the Endangered Species Act. Construction activities will cease if listed marine species are observed entering the active project construction site, and work will be allowed to resume only after the listed species departs the construction site on its own volition. The Pacific Islands Area Office of National Marine Fisheries Service (NMFS) will be notified of each such occurrence. Both the U.S. Fish and Wildlife Service and NMFS have concurred that neither listed species nor their habitat would be adversely impacted by normal construction activities associated with the deep ocean outfall. In the unlikely event that ordnance material is encountered that DON cannot safely remove or avoid, DON will, as appropriate, confer with NMFS before proceeding

with construction in the area of the discovered ordnance material.

Public Health and Safety

There is potential for impacts on public health and safety from encountering ordnance items in the construction corridor. Approximately two hundred dives were performed between November 1999 and December 2000 along the proposed construction corridor and along the Pearl Harbor Entrance Channel (PHEC). These dives identified six projectiles within the proposed construction corridor. These six projectiles were subsequently removed safely without in-water detonation. Based on information collected from these dives, it is likely that ordnance can be safely removed or avoided if it is encountered. The construction contractor will perform an independent survey for ordnance items by visual and/or remote metallic detection methods prior to construction. All workers will be informed of the ordnance hazards before construction activities begin. Public access to construction areas will be restricted. If an ordnance item is encountered during construction, work will stop in the affected area pending DON clearance.

RESPONSE TO COMMENTS RECEIVED REGARDING THE FEIS

EPA and a commercial entity provided comment letters. EPA's comments focused on construction related impacts to living coral and suitability of dredged material for ocean disposal.

EPA requested that DON include the following mitigation: take "appropriate and practicable steps" to minimize adverse impacts to corals; transplant living corals away from project area; and remove marine debris from the vicinity of the PHEC to generally enhance marine habitat. No exceptional, unusual, or large coral colonies are within the project area and, as discussed in the FEIS, potential impacts to the coral that is present have been minimized by careful selection of the outfall alignment and construction methodology (e.g., microtunneling and the use of silt curtains). Transplanting the small number of corals in the construction corridor that cannot be avoided is considered impracticable. The removal of marine debris from the vicinity of the PHEC would eliminate and degrade fish and threatened green sea turtle (Chelonia mydas) habitat because it is heavily utilized by these species.

EPA also requested additional discussions on the suitability of the dredged material for ocean disposal. Pursuant to Section 103 of the Marine Protection Research Sanctuaries Act, DON has provided this information as part of the permitting process regulated by the U.S. Army Corps of Engineers (COE) and the EPA. The COE permit application included data indicating that the material proposed for disposal will be substantially the same as the existing substrate at the EPA designated South Oahu Ocean Dredged Material Disposal Site and that the proposed dredged material site is located far from known pollution sources, therefore providing reasonable assurance that the material has not been contaminated. The COE permit will address concerns regarding ocean disposal.

The F.O.G. Corporation recommended use of its liquid bio-polymer to meet EPA discharge requirements and avoid construction of the outfall. The recommended bio-polymer product does not include removal of dissolved nutrients and therefore is not a viable alternative to the proposed action.

CONCLUSION

In determining how to dispose of wastewater effluent from the WWTP at Fort Kamehameha, I considered the following: present ability of the WWTP to comply with more stringent anticipated discharge wastewater effluent limits; technical feasibility; operational reliability; environmental impacts; costs associated with construction, operation, and maintenance of facilities; and comments received during the DEIS and FEIS public involvement periods.

After carefully weighing all of these factors and analyzing the data presented in the FEIS, I have determined that the preferred alternative, constructing a deep ocean outfall to replace the existing outfall, best meets the requirements for the disposal of wastewater effluent from the WWTP at Fort Kamehameha. Therefore, on behalf of the DON, I have decided to implement the proposed action by constructing a deep ocean replacement outfall and to retain the existing outfall for emergency bypass purposes. In addition to the specific mitigation measures identified in this ROD, the DON will continue to review its operational procedures and coordinate with other federal, state, and

local entities as necessary to determine if any additional mitigation measures are feasible and practicable.

6/22/01
Date

Duncan Holaday
Deputy Assistant Secretary
of the Navy
(Installations and Facilities)

Final Environmental Impact Statement
Outfall Replacement for Wastewater Treatment Plant at Fort Kamehameha, Navy Public Works Center, Pearl Harbor, Hawaii

Lead Agency: Navy Public Works Center, Pearl Harbor, Hawaii

Coordinating Agency: Pacific Division, Naval Facilities Engineering Command
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Abstract:

This environmental impact statement (EIS) evaluates replacement of the existing outfall from the Wastewater Treatment Plant (WWTP) at Fort Kamehameha. The proposed action is to construct a new effluent outfall into the Open Coastal Waters offshore of Fort Kamehameha.

Presently, the effluent outfall for the WWTP at Fort Kamehameha discharges into the Pearl Harbor Estuary. This area is classified as a Water Quality Limited Segment (WQLS) by the State of Hawaii Department of Health. Under this classification, discharge of municipal and industrial wastewater effluents to the estuary is limited. Relocation of the effluent discharge to Open Coastal Waters will eliminate effluent discharge to the WQLS of the Pearl Harbor Estuary and the associated future permit limitations and violations.

The proposed action is to construct a 3.9-kilometer (2.4-mile)-long, 107-centimeter (42-inch)-diameter outfall, terminating in a 200-meter (656-foot)-long diffuser at a depth of 46 meters (150 feet). The preliminary alternatives to the proposed action, which are considered in this EIS, include underground injection, no action, treatment plant upgrade, infiltration and evaporation, and effluent reuse. A preliminary screening identified underground injection as the only feasible alternative to the proposed action.

Based on a detailed analysis of the environmental impacts of the proposed action and the underground injection and no-action alternatives, the proposed action with mitigation as stipulated was found to be the environmentally preferred alternative. There are no identified unmitigable, significant environmental impacts expected as a result of implementing the proposed action. The proposed action is consistent with applicable state and federal water quality and air quality standards.

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ABBREVIATIONS AND ACRONYMS

°C	degree Celsius
°F	degree Fahrenheit
µg/l	micrograms per liter
ac	acre
AFB	Air Force Base
BMP	Best Management Practices
BOD	biochemical oxygen demand
BOD_5	5-day biochemical oxygen demand
BWS	Board of Water Supply
CAA	Clean Air Act
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
cfu	colony forming units
City	City and County of Honolulu
cm	centimeter
cm/year	centimeter per year
CWA	Clean Water Act
CZM	Coastal Zone Management
DA	Department of the Army
DBEDT	Department of Business, Economic Development, and Tourism
DEIS	Draft Environmental Impact Statement
DLNR	Department of Land and Natural Resources
DoD	Department of Defense
DOH	Department of Health
DWM	Department of Wastewater Management
EA	Environmental Assessment
EDR	electrodialysis reversal
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EMR	electromagnetic radiation
EOD	Explosive Ordnance Disposal
ESA	Endangered Species Act
ESQD	explosive safety quantity distance
FAA	Federal Aviation Administration
FEIS	Final Environmental Impact Statement
FMP	Fishery Management Plan
ft	foot
ft/day	foot per day
ft^2	square foot
g/m^2	grams per square meter
GAC	granular activated carbon
gal	gallon
ha	hectare
HIANG	Hawaii Air National Guard
HAR	Hawaii Administrative Rules
HAPC	Habitat Areas of Particular Concern
HDPE	high-density polyethylene
HECO	Hawaiian Electric Company, Inc.
HERF	Hazards of Electromagnetic Radiation to Fuels

HERO	Hazards of Electromagnetic Radiation to Ordnance
HERP	Hazards of Electromagnetic Radiation to Personnel
HWWTP	Honouliuli Wastewater Treatment Plant
km	kilometer
kW	kilowatt
kWh	kilowatt hour
kV	kilovolt
lb/ft^2	pound per square foot
m	meter
m/day	meter per day
m^2	square meter
m^3	cubic meter
m^3/day	cubic meter per day
MBS	Mamala Bay Study
mgd	million gallons per day
mg/Kg	milligram per kilogram
mg/l	milligram per liter
mi	mile
ml	milliliter
MOA	Memorandum of Agreement
MPRSA	Marine Protection, Research, and Sanctuaries Act
msl	mean sea level
n/a	not available
NAAQS	National Ambient Air Quality Standards
NAGPRA	Native American Graves Protection and Repatriation Act
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NOTAM	Notice to Airmen
NOTMAR	Notice to Mariners
NPDES	National Pollutant Discharge Elimination System
NPSP	nonpoint source pollution
NRHP	National Register of Historic Places
ntu	nephelometric turbidity units
O&M	operations and maintenance
ODMDS	Ocean Dredged Material Disposal Site
PACNAVFACENGCOM	Pacific Division, Naval Facilities Engineering Command
PCBs	polychlorinated biphenyls
PVC	polyvinyl chloride
PWC	Navy Public Works Center, Pearl Harbor
RCP	reinforced concrete pipe
RCRA	Resource Conservation and Recovery Act
RO	reverse osmosis
ROD	Record of Decision
RSB	Roberts, Snyder and Baumgartner (model)
SAAQS	State Ambient Air Quality Standards
SDZ	Surface Danger Zone
SHPO	State Historic Preservation Officer
SIWWTP	Sand Island Wastewater Treatment Plant

SOPs	standard operating procedures
TSS	total suspended solids
UBC	Uniform Building Code
UIC	Underground Injection Control
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
UV	ultraviolet
UXO	unexploded ordnance
WQLS	Water Quality Limited Segment
WPRFMC	Western Pacific Regional Fishery Management Council
WWTP	wastewater treatment plant
yd^3	cubic yard
ZOM	zone of mixing

TABLE OF CONVERSION FACTORS

Multiply	By	To Obtain
°C	[1.8 x (°C)] + 32	°F
centimeter (cm)	0.3937	inch
cubic meter (m^3)	1.308	cubic yard (yd^3)
cubic meter (m^3)	264.2	gallon (gal)
hectare (ha)	2.471	acre (ac)
kilogram	2.205	pound
kilometer (km)	0.6214	mile (mi)
liter	0.2642	gallon (gal)
meter (m)	3.281	feet (ft)
meter (m)	0.547	fathom
metric ton	1.103	ton
microgram (μg)	2.2×10^{-9}	pound
milligram (mg)	2.2×10^{-6}	pound
milliliter (ml)	0.0021	pint
square meter (m^2)	10.76	square foot (ft^2)

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

Summary of Findings

The proposed action is to construct a deep ocean effluent outfall for the Wastewater Treatment Plant (WWTP) at Fort Kamehameha. The proposed outfall will discharge into the Open Coastal Waters of Mamala Bay outside of the Pearl Harbor Entrance Channel. Alternatives to the proposed action taken into consideration include underground injection, no action, treatment plant upgrade, infiltration and evaporation, and effluent reuse. The no-action alternative consists of continued use of the existing outfall, which discharges into the Pearl Harbor Estuary. Future regulatory conflicts that include potential noncompliance with increasingly stringent discharge limitations in the estuary are associated with this alternative.

There are no identified, unmitigable, significant impacts associated with the proposed action. Mitigation has been incorporated into design features (including outfall alignment, depth, and length of diffuser) and implemented through procedural actions (such as construction specifications, silt containment, and navigational warnings). The proposed action with mitigation as stipulated is the environmentally preferred alternative.

Methodology

Alternatives to the proposed action that would remove the effluent discharge from the Pearl Harbor Estuary were considered. Conceptual designs and cost estimates for the alternatives, which included underground injection, no action, treatment plant upgrade, infiltration and evaporation, and effluent reuse, were developed. All alternatives, except the no-action alternative, were configured to be similar in capacity to the existing outfall and to meet applicable regulatory requirements. The relative costs of the proposed action and alternatives differ significantly. The replacement ocean outfall has an anticipated life-cycle cost of approximately $21.6 million; underground injection has a corresponding life-cycle cost of approximately $35 million; the no-action alternative is least expensive, with a 30-year life-cycle cost of approximately $1.5 million; WWTP upgrade has estimated life-cycle costs ranging from $70 million to $144 million; infiltration and evaporation methods have land acquisition costs ranging from $160 million to $4.5 billion; and reuse has an estimated net life-cycle cost of $117 million, based on the assumption that the wastewater effluent would be sold at the current rate for nonpotable water.

As the conceptual designs and cost estimates for the alternatives were being produced, various outfall alignment options and two diffuser options were studied in order to develop and refine the proposed action. The development of the proposed action was an iterative process in which the alignment and construction methods were analyzed and modified numerous times to minimize environmental impacts and reduce construction risks.

A preliminary evaluation, or screening, of the proposed action and alternatives was performed. The capacity for each alternative to satisfy the purpose of and need for the project and the potential environmental effects of each alternative were evaluated. Those alternatives that passed the screening (i.e., met the purpose and need, were feasible to implement, and had acceptable potential environmental effects) were determined to be feasible alternatives and carried forward for a more detailed environmental impacts analysis. Those that did not pass the screening were eliminated from further evaluation with the exception of no action, which must be analyzed in accordance with 40 Code of Federal Regulations 1502.14(d) and 1502.16(d). Based on the

screening of the proposed action and alternatives considered, the treatment plant upgrade, infiltration and evaporation, and effluent reuse alternatives were eliminated from further analysis because they did not meet the purpose of and need for the project and/or were infeasible to implement. Thus, a more detailed environmental analysis of the proposed action, underground injection, and no-action alternatives was performed for comparison and to refine necessary mitigation.

Significant issues and potentially significant impacts identified during scoping were examined in detail. These include: effects on the aquatic environment (including water quality), socioeconomic impacts, protected species, cultural resources, public health and safety, navigation, and water as a resource. Numerous other issues were eliminated from detailed evaluation since they were not potentially significant or applicable. The rationale for determining that each of these issues is nonsignificant is briefly presented. Feasible alternatives were evaluated to determine the effect each would have with regard to the significant issues. Selected impact parameters were then identified and evaluated according to significance factors to compare the magnitude and significance of impacts resulting from each feasible alternative.

Impacts Analysis

Aquatic Environment

Effects on the aquatic environment vary among the alternatives. Detrimental but nonsignificant effects were identified for the proposed outfall replacement. All known impacts of the proposed action on the marine environment were considered cumulatively with other discharges to Mamala Bay. The discharged effluent is presently treated to a secondary level and sand filtered. The effluent meets whole effluent toxicity and disinfection requirements. The proposed action meets the project's intended purpose of removing the discharge from nearshore waters. Because the treatment processes will not be affected by construction or operation of the proposed outfall, the proposed action will not affect the present quality or disinfection of the effluent. Underground injection of effluent would result in subsurface flow of effluent to the marine environment at unknown concentrations and coastal locations, potentially impacting nearshore water quality. The no-action alternative would continue the nearshore discharge and, if the influent flow to the WWTP were to increase within the plant's present capacity, there would be potential to adversely impact the water quality of the estuary or to exceed anticipated discharge permit limitations.

Socioeconomic Effects

Although some temporary disruption of existing recreational, commercial, and personal consumptive uses of the project area would occur during construction of the replacement outfall, the area would be returned to use following approximately two years of construction. Because the entire project would take place within controlled access military property and within the Pearl Harbor Naval Defensive Sea Area, military personnel and dependents would be most affected. The effects of the proposed action on socioeconomic activities will not be significant. There is potential for the underground injection alternative to impact nearshore water quality in areas where socioeconomic activities occur. No action would not affect existing socioeconomic practices.

Protected Species

The only federally protected species known to inhabit or occasionally visit the project area are the threatened green sea turtle and the endangered Hawaiian stilt. Construction activities for the proposed action would not likely adversely affect these species. The underground injection and

no-action alternatives would avoid possible adverse effects on these animals from construction. Operations of the proposed action or feasible alternatives would not adversely affect protected species.

Cultural Resources

The replacement outfall and no-action alternatives are not anticipated to affect cultural resources. The underground injection alternative has the potential for adverse impacts resulting from the necessary excavation in locations known to have a history of human occupation and burials. The significance of this potential impact cannot be determined beforehand because it is not possible to foresee the exact location and extent of such remains.

Public Health and Safety

The potential danger of encountering ordnance items during construction of the replacement outfall will be mitigated by preceding construction activities with a search for ordnance items, by minor outfall realignment, if necessary, to avoid disturbance of ordnance items, and by implementing safety protocols. It is unlikely that ordnance items would be encountered during construction of the underground injection alternative. No construction activities are proposed for the no-action alternative. Routine construction safety issues are associated with the proposed action and underground injection alternatives; all of these can be mitigated by implementation of standard construction safety measures.

Because of the degree of treatment and disinfection provided at the WWTP at Fort Kamehameha, potential harm to public health from exposure to effluent is not significant for any of the feasible alternatives.

Navigation

Construction barges for the proposed action will obstruct approximately one third of the width of the Pearl Harbor Entrance Channel for a period of up to eight months. This will only interfere with passage of aircraft carriers into the harbor, which occurs about two times per year. Mitigation would require the removal of construction equipment to allow passage of these vessels into Pearl Harbor. Potential interference with navigation of other vessels will be mitigated by coordinating with the Coast Guard and Naval Station Port Operations, publishing Notices to Mariners (NOTMAR), and placing proper warning and anchor lighting at the construction barge anchor locations. The elevated section of the proposed replacement outfall and the existing outfall pipe could potentially be damaged by emergency anchoring of a vessel. However, the degree of risk associated with such an incident is deemed to be nonsignificant. The underground injection alternative will not impact sea navigation, because both construction and operational activities of underground injection wells are on land. No construction activities will occur as a result of no action; therefore, this alternative will have no impacts on sea navigation.

Air navigation is not significantly affected by any alternative. Although an approach from the southwest to Honolulu International Airport and/or Hickam Air Force Base occurs over the project site, the height of construction equipment for the proposed action and underground injection alternative would be below an altitude that would pose an obstruction hazard to aircraft. As a routine procedure, the Navy will obtain a Notice of Proposed Construction permit from the Federal Aviation Administration (FAA) prior to commencement of any construction potentially affecting navigable air space. The FAA will distribute a Notice to Airmen (NOTAM) warning to aircraft.

Water as a Resource

Water resources will not be significantly impacted by the proposed action or by the underground injection or no-action alternatives.

Summary of the Preferred Alternative and Associated Mitigation, Significant Impacts that Cannot Be Mitigated, and Unresolved Issues

In consideration of the above factors, the preferred alternative is to construct a deep ocean outfall 3.9 kilometers (2.4 miles) long, terminating in a 200-meter (m) (656-foot [ft])-long diffuser at a depth of 46 m (150 ft). The outfall pipe, approximately 107 centimeters (42 inches) in diameter, is to be buried in the shallow reef flat and in the Pearl Harbor Entrance Channel. The diffuser, placed horizontally on a sloping, sandy bench, will be supported on piles. The proposed outfall alignment from the treatment plant is south across the reef flat to the entrance channel. From this location seaward, the bottom of the entrance channel is sand and coral rubble. This alignment avoids an area of deep, soft soil which is incapable of adequately supporting the outfall pipe and areas with higher densities of living coral. The outfall follows the east wall of the Pearl Harbor Entrance Channel to a submerged shelf in the offshore slope at a depth of 46 m (150 ft).

No unmitigable significant impacts will result from implementation of the preferred alternative. The only unresolved issue is the size and configuration of the zone of mixing (ZOM), which will be assigned during National Pollutant Discharge Elimination System permitting to be undertaken prior to operation of the outfall. The permit application, pursuant to Hawaii Administrative Rules, Chapter 11-54-09, will request a ZOM approximately 910 m (2,980 ft) by 750 m (2,460 ft). These estimated dimensions have been determined by the application of approved dilution modeling methods. Mitigation measures, other than those integrated into the outfall design, include standard construction measures for traffic and workplace safety, NOTMAR and NOTAM publications, proper marking and lighting of navigational hazards, silt containment measures during construction, coordination with Naval Station Port Operations to avoid constraining large vessel access to the channel, and restoration of the work site and benthic environment to approximately original contours following construction.

Compliance with Applicable Policies and Regulations

The preferred alternative minimizes impacts on living coral, does not have disproportionately high or adverse impacts on minority, low-income or disadvantaged populations, and complies with other applicable policies and regulations. The project is in an air quality attainment region and is in conformance with federal and state air quality standards.

Construction of the replacement outfall would require a Department of the Army permit under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act. Water Quality Certification under Section 401 of the Clean Water Act and approval to discharge a regulated pollutant under Section 402 of the Clean Water Act (National Pollutant Discharge Elimination System) are required from the State of Hawaii Department of Health. The proposed action is expected to meet the requisite qualifications for approval, subject to conditions, under these statutes.

CHAPTER ONE

PURPOSE AND NEED

CHAPTER ONE
PURPOSE AND NEED

1.1 Introduction

The Pacific Division, Naval Facilities Engineering Command, on behalf of Navy Public Works Center, Pearl Harbor (PWC), has prepared this environmental impact statement (EIS) for outfall replacement at the Wastewater Treatment Plant (WWTP) at Fort Kamehameha. This EIS is prepared in accordance with the National Environmental Policy Act of 1969 and the implementing regulations of the Council on Environmental Quality regulations 40 Code of Federal Regulations (CFR) 1500 to 1508.

The proposed action covered by this EIS is replacement of the existing outfall that discharges treated wastewater effluent from the WWTP at Fort Kamehameha into the Pearl Harbor Estuary. The proposed replacement outfall will discharge effluent through a multiport diffuser[1] into the deeper waters of Mamala Bay. Figure 1.1-1 shows the existing WWTP and proposed replacement outfall.

This chapter explains the purpose of and need for the proposed federal action, provides background information, and describes the organization of this EIS.

1.2 Purpose of and Need for Proposed Action

The Hawaii Department of Health (DOH) limits the discharge of additional pollutants to the Pearl Harbor Estuary. The WWTP has recently been upgraded to improve the level of treatment and provide additional capacity. The existing outfall is damaged and aging and requires repair or replacement. According to a 1983 inspection report, along one section of the outfall {between 357 and 375 meters (m) (1,170 and 1,230 feet [ft]) from shore}, the pipe is undercut with several lateral penetrations up to 0.9 m (3 ft) deep. Approximately 363 m (1,190 ft) from shore, a small section of the concrete jacket is missing. The terminal plug of the outfall is also not in place.[2] More recently, there have been reports that some existing diffuser ports are broken.[3]

The purpose for which this action is proposed is to reduce pollutant loadings from the wastewater discharge into the Water Quality Limited Segment (WQLS) of the Pearl Harbor Estuary[4] as shown in Figure 1.2-1 (see Appendix I). The needs, which the project satisfies, are to comply with regulatory limits that are anticipated to be imposed on discharges to the WQLS in the future and to provide an effluent disposal system that satisfies the following feasibility criteria:

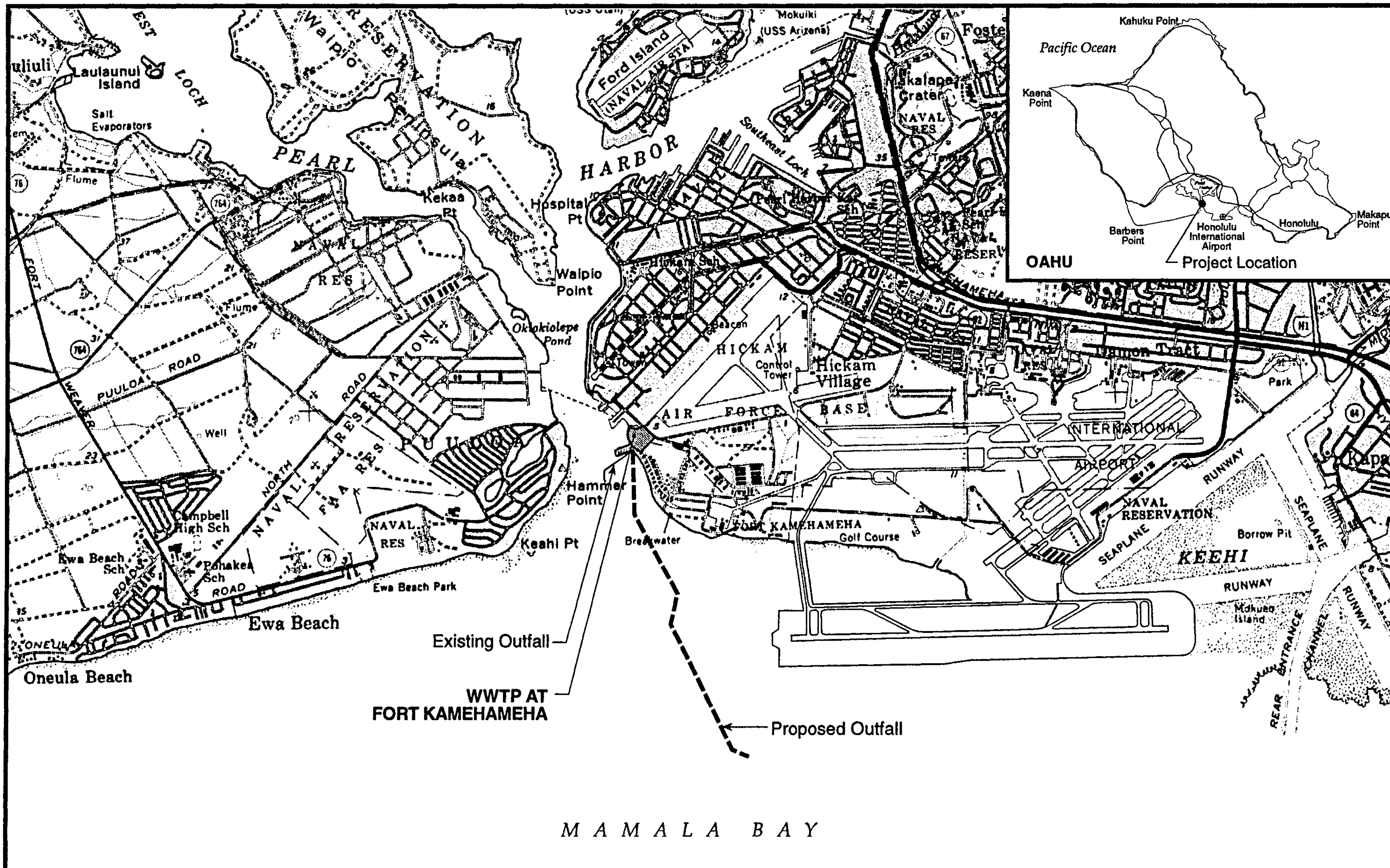
- Meets all environmental and other regulatory constraints,
- Is similar in capacity and operational reliability to the existing outfall system, and

[1]A diffuser is a section of pipe with multiple openings to disperse effluent into the receiving water for enhanced dilution.

[2]Richard W. Grigg, Ph.D. and Hans Krock, Ph.D., P.E. (March 1983) *Outfall Inspection of Fort Kamehameha Wastewater Treatment Plant, Pearl Harbor, Hawaii.* Prepared for Pacific Division, Naval Facilities Engineering Command, Pearl Harbor, Hawaii.

[3]Written communication from Sea Engineering, Inc. (March 12, 1997).

[4]Pearl Harbor Estuary is one of 14 WQLS located in Hawaii. WQLS were designated by the DOH in response to Section 303(e) of the Federal Water Pollution Control Act of 1972. No new wastewater discharges are permitted into the Pearl Harbor Estuary, and special water quality standards have been established by DOH for the estuary.



Source: Topographic map of Oahu (USGS, 1954)

Figure 1.1-1
EXISTING WWTP AND PROPOSED OUTFALL
EIS for Outfall Replacement, WWTP at Fort Kamehameha
March 2001

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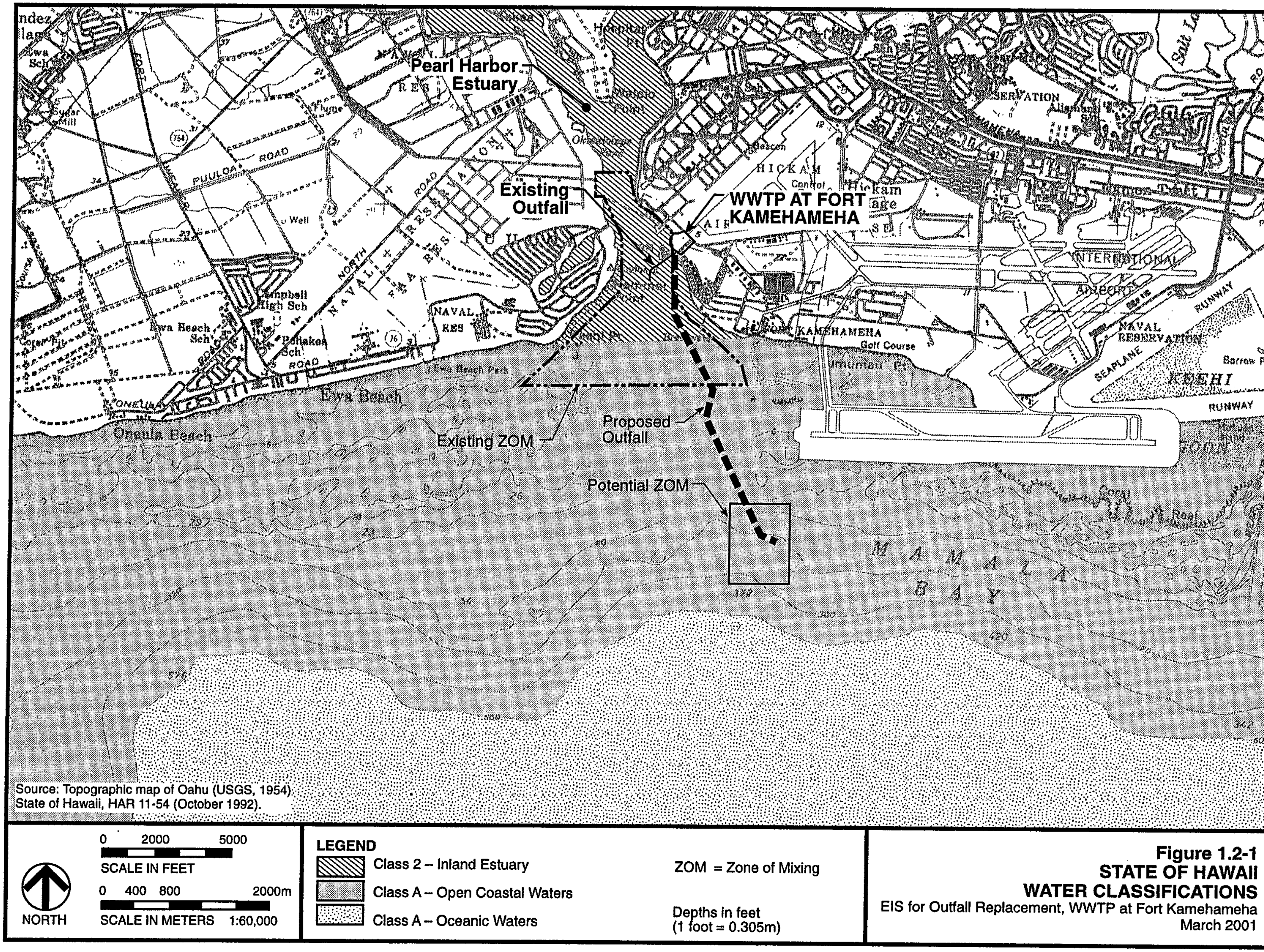

Figure 1.2-1
STATE OF HAWAII
WATER CLASSIFICATIONS
EIS for Outfall Replacement, WWTP at Fort Kamehameha
March 2001

- Is economically competitive with other disposal options for acquisition under prevailing standards.

The existing National Pollutant Discharge Elimination System (NPDES) permit for discharge of effluent from the WWTP at Fort Kamehameha expired on February 28, 1993. The WWTP is currently discharging under an administrative extension from the DOH, which administers the NPDES program in Hawaii for the U.S. Environmental Protection Agency (USEPA). Although the permit renewal has not been negotiated, the USEPA has indicated its intention to limit the discharge of nutrients and metals to the Pearl Harbor Estuary to levels below those of the existing discharge (see Appendix I). Relocating the effluent discharge to the Open Coastal Waters of Mamala Bay removes the discharge from the Pearl Harbor Estuary, a WQLS, where it is anticipated that permit limitations will become increasingly stringent, making it difficult to remain in compliance.

1.3 Evaluation of Proposed Action and Alternatives

Several alternatives to the proposed action were considered. These alternatives included underground injection of effluent, no action (i.e., the continued use of the existing outfall indefinitely into the future), WWTP upgrade, infiltration and evaporation, and effluent reuse. A preliminary evaluation, or screening, of the proposed action and these alternatives was performed based on each alternative's ability to meet the purpose and need, including the identified feasibility criteria. Those that did not "pass" the screening were eliminated from further evaluation. The proposed action and underground injection passed the initial evaluation and underwent detailed analysis to determine and compare the extent of their environmental impacts. The no-action alternative, which does not meet the purpose and need, was also subjected to detailed environmental analysis in accordance with 40 CFR 1502.14(d) and 1502.16 (d). The preferred alternative was determined based on the results of the detailed environmental impacts analysis in Chapter 4.

1.4 Summary of Preferred Alternative

The preferred alternative is the proposed action, construction of a replacement outfall which discharges outside the Pearl Harbor Estuary into the Open Coastal Waters of Mamala Bay. This involves installation of a 3.9-kilometer (km) (2.4-mile [mi])-long, 107-centimeter (cm) (42-inch)-diameter outfall pipe. The outfall will terminate with a diffuser approximately 1.0 km (0.6 mi) offshore from the western end of the Honolulu International Airport's Reef Runway. The outfall and diffuser will be designed to release the effluent over a given discharge length and to dilute or "diffuse" the effluent into the marine waters. A portion of the outfall pipe will be buried beneath the ocean floor to reduce the potential for interference with coastal processes and activities, damage by ships' anchors, and natural disturbances such as hurricanes. The existing outfall will be left in place for backup (emergency) use.

The preferred alternative analysis also evaluates the alignment of the proposed replacement outfall and the length and depth of the diffuser. Variations include placing the diffuser at a water depth of either 21 m (70 ft) or 46 m (150 ft), varying its length, altering the alignment of the outfall pipe from the WWTP to the diffuser, and altering outfall construction methods. Figure 1.4-1 shows possible outfall alignment and diffuser location options.

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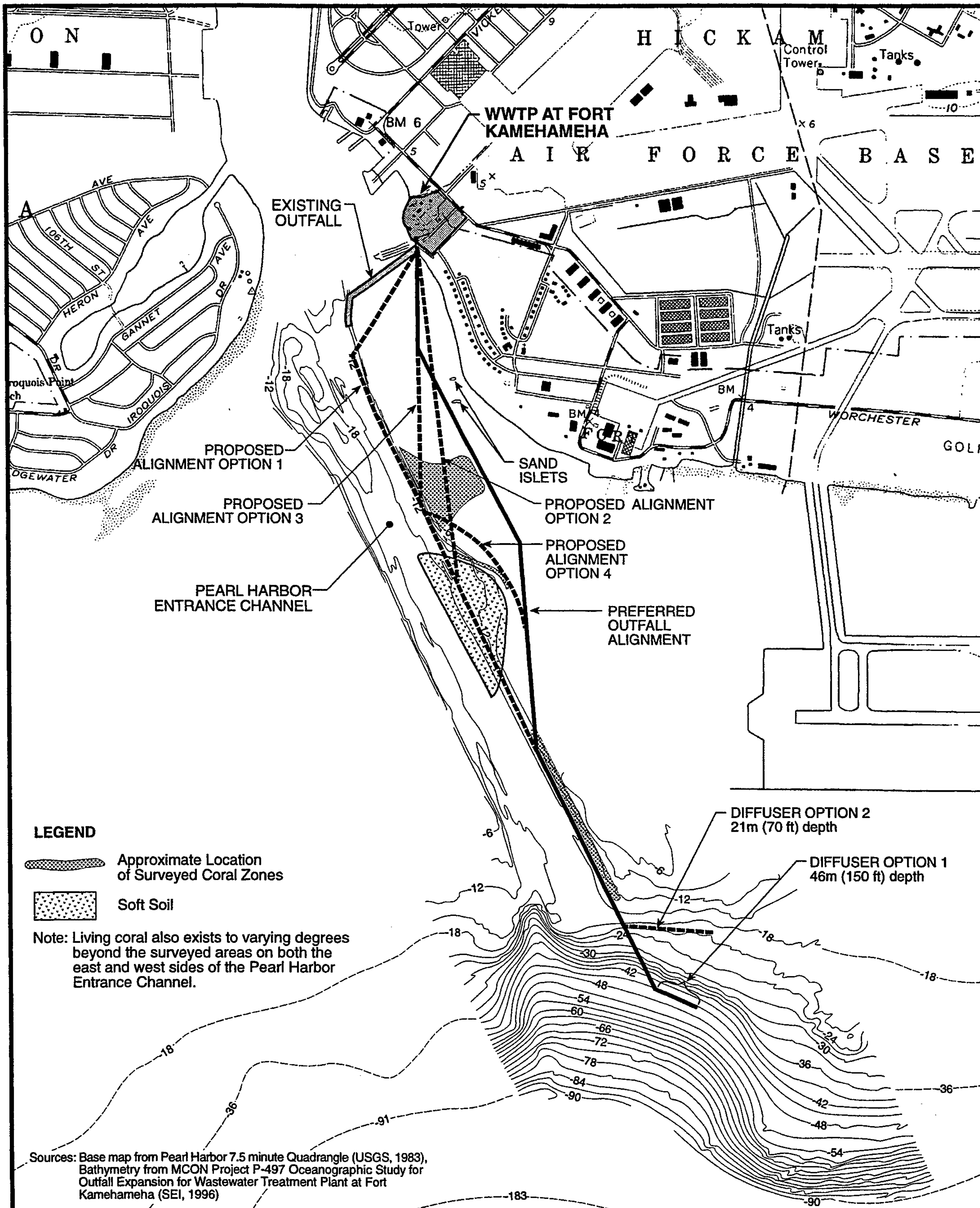

LEGEND

Approximate Location of Surveyed Coral Zones

Soft Soil

Note: Living coral also exists to varying degrees beyond the surveyed areas on both the east and west sides of the Pearl Harbor Entrance Channel.

Sources: Base map from Pearl Harbor 7.5 minute Quadrangle (USGS, 1983), Bathymetry from MCON Project P-497 Oceanographic Study for Outfall Expansion for Wastewater Treatment Plant at Fort Kamehameha (SEI, 1996)

NORTH

0 1000 2000
SCALE IN FEET

0 200 500m
SCALE IN METERS 1:24,000

LEGEND

-6- Bathymetry (in meters) from USGS topographic map

-6- Bathymetry (in meters) from SEI study

Note: Depth in meters (1m=3.28 ft)

Figure 1.4-1
PROPOSED OUTFALL ALIGNMENT & DIFFUSER ALTERNATIVES
EIS for Outfall Replacement, WWTP at Fort Kamehameha
March 2001

1.5 Decision Required

The decision maker for this EIS is the Deputy Assistant Secretary of the Navy (Installations and Facilities). The specific decisions for which this EIS has been prepared are as follows:

- Whether or not to replace the existing outfall, and
- If the existing outfall is to be replaced, which of the alternatives will be used to dispose of the effluent.

1.6 Background and Context

There is a history of concern over cumulative impacts of WWTP discharges into Mamala Bay. Numerous studies have been conducted in connection with effluent disposal into Mamala Bay. This EIS acknowledges these studies and has used them as reference material in the evaluation of impacts of the proposed action. This section is designed to summarize the history of wastewater disposal in Mamala Bay and to describe these studies in the context of this EIS.

1.6.1 Wastewater Disposal in Mamala Bay

Three WWTPs currently discharge treated effluent into Mamala Bay: the Honouliuli Wastewater Treatment Plant (HWWTP) and the Sand Island Wastewater Treatment Plant (SIWWTP), both owned and operated by the City and County of Honolulu (City); and the WWTP at Fort Kamehameha, owned and operated by the U.S. Navy. Figure 1.6-1 illustrates the location of these WWTPs and their associated outfalls. Table 1.6-1 provides information on each of these WWTPs.

Table 1.6-1
Information on WWTPs Discharging Into Mamala Bay

WWTP	Date of Construction	Current Plant Design Flow in m^3/day (mgd)*	Average Depth of Outfall in m (ft)
Sand Island WWTP	Outfall - 1975 Phase 1 - 1976 Phase 2 - 1979	310,000 (82)	70 (230)
Honouliuli WWTP	Outfall - 1979 Original plant - 1984 Upgrade capacity - 1992 Upgrade level of treatment - 1997	140,000 (37)	62 (203)
WWTP at Fort Kamehameha	1969 1996-97 - Upgrade capacity and level of treatment	49,000** (13)	14 (46)

* Design flow is defined as average daily flows generated by population and land use; m^3/day = cubic meter per day; mgd = million gallons per day

** Design flow based upon recently completed upgrades to the WWTP at Fort Kamehameha.

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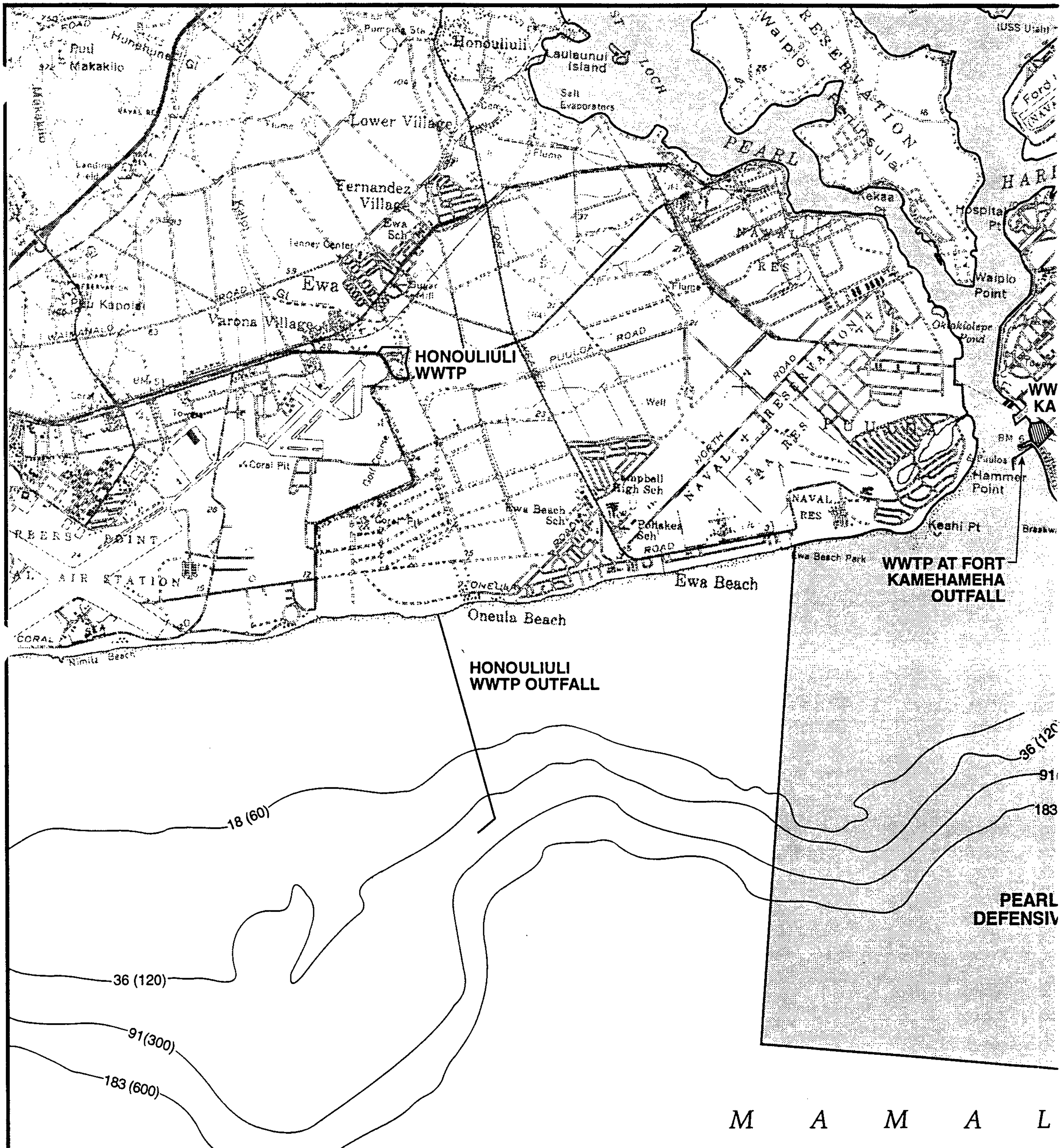


0 2000 5000
SCALE IN FEET

0 400 800 2000
SCALE IN METERS 1:60,000

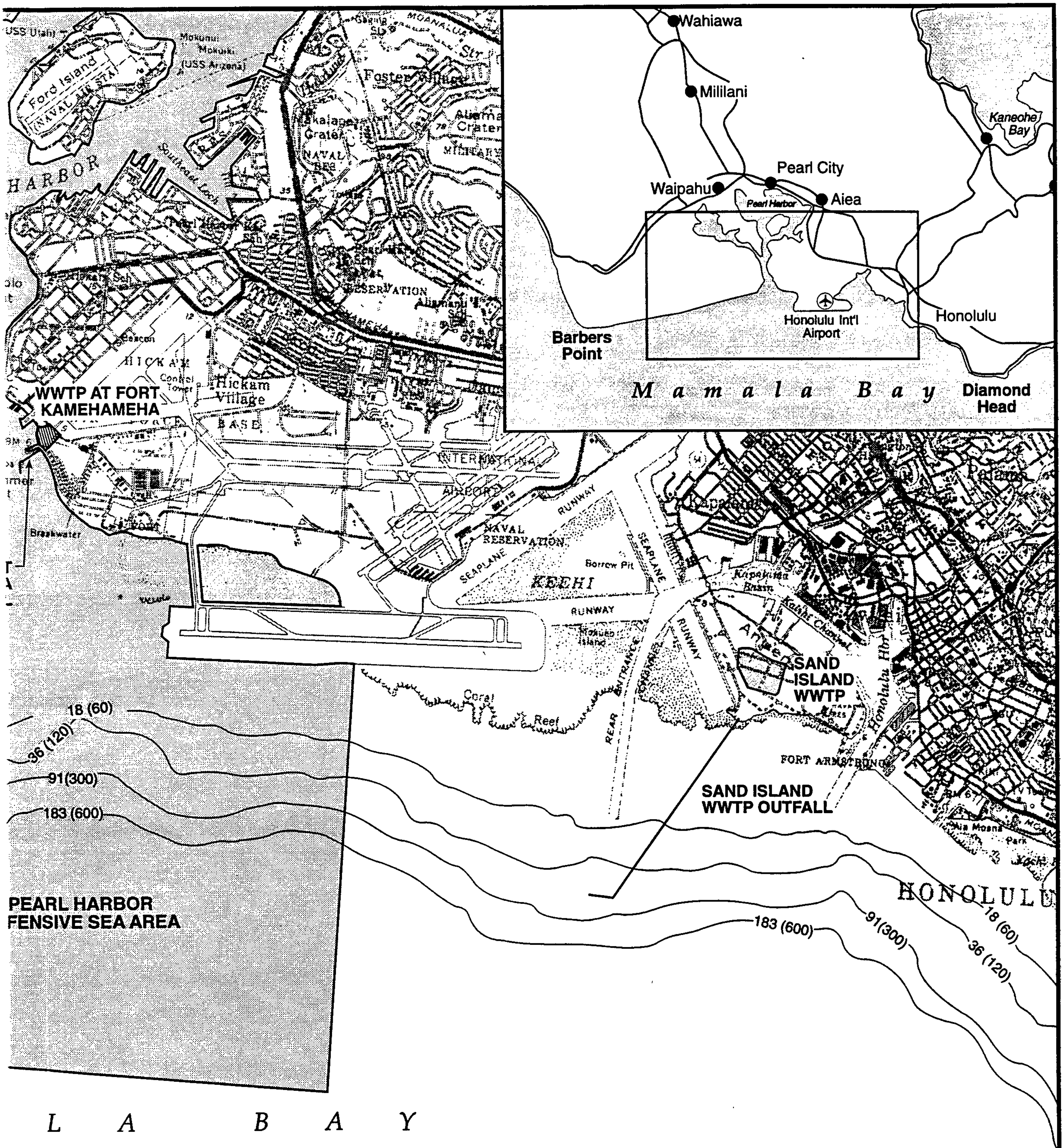
NORTH

Source: Mamala Bay Study, 1996, Hawaii Military Land Use Mast
1995 Topographic map of Oahu (USGS, 1954).

Note: Locations of outfalls and defensive sea area boundary are approximate, based on source data.

Bathymetry in meters (feet)

(1)



Use Master Plan,

dary

Figure 1.6-1
LOCATION OF EXISTING WWTP OUTFALLS, MAMALA BAY

EIS for Outfall Replacement, WWTP at Fort Kamehameha
March 2001

(2)

The SIWWTP is currently operating at approximately 97.5 percent of its capacity.[5] Facilities plans have been or are currently being developed for the projected needs of the East Mamala Bay and West Mamala Bay wastewater systems, in which the SIWWTP and HWWTP, respectively, are located. The East Mamala Bay Wastewater Facilities Plan modeled the future needs for additional capacity at the SIWWTP, based on population and land use. The models predicted that by the year 2015, average daily flow would be approximately 340,000 m^3/day (90 mgd), exceeding the SIWWTP design capacity of 310,000 m^3/day (82 mgd). The West Mamala Bay Wastewater Facilities Plan is still being prepared, and no projected flows are available.

Average daily flow to the WWTP at Fort Kamehameha in 1992 was approximately 27,252 m^3/day (7.2 mgd) or about 96 percent of the plant's capacity at that time. The treatment plant has recently been upgraded to a new design capacity of 49,000 m^3/day (13 mgd). The WWTP at Fort Kamehameha is presently operating at approximately 50 percent of the plant's new design capacity.[6] Details of this upgrade are provided in Section 1.7 of this document.

1.6.2 Related Documents

A number of studies have been conducted regarding wastewater disposal in Mamala Bay and the ocean disposal of dredged material at designated disposal sites. Many of these documents have been used as reference material for this EIS; the major documents and their contents are summarized in this section.

Environmental Assessment (EA) for Expansion of WWTP at Fort Kamehameha - On the basis of the predicted increase in average daily flow, the U.S. Navy proposed expansion of the WWTP at Fort Kamehameha to handle an average daily flow of 49,000 m^3/day (13 mgd). An EA was prepared to study the potential impacts of this plant expansion.[7] This document also considered alternatives to the proposed expansion, which included no action, constructing a new plant, and diverting a portion of the flow to the municipal system. Construction of a new plant to treat either 49,000 m^3/day (13 mgd) or 19,700 m^3/day (5.2 mgd) was not selected because of cost, land, and site development issues. Diverting 19,700 m^3/day (5.2 mgd) of the wastewater to the City municipal wastewater system, where it would be treated at the SIWWTP, was not selected because of the capacity restraints on the City facility, uncertainties surrounding the granting of easements, and higher costs. The EA concluded that the proposed expansion to the east of the existing facilities best met the selection criteria and would not have unmitigable adverse impacts.

Documents Associated with the SIWWTP - The appropriate level of wastewater treatment prior to discharge to Mamala Bay has been debated for many years. In 1990, legal action was taken by the Sierra Club Legal Defense Fund and Hawaii's Thousand Friends against the City, alleging violation of the Clean Water Act and the terms and conditions of the NPDES permit by failing to upgrade the HWWTP and SIWWTP to secondary treatment. This legal action resulted in a consent decree being issued by the U.S. District Court in November 1991. The consent decree created the Mamala Bay Study Commission and imposed completion deadlines for preparation of the East Mamala Bay Facilities Plan (which includes the SIWWTP) and the associated EIS.

[5] Belt Collins & Associates (August 1992) *Expansion of the Wastewater Treatment Plant at Fort Kamehameha Environmental Assessment.* Prepared for the Department of the Navy, Public Works Center.

[6] U.S. Navy (September 1997 - September 1998) *National Pollutant Discharge Elimination System (NPDES) Discharge Monitoring Report (DMR) for Fort Kamehameha Facility at Hickam Air Force Base.*

[7] Belt Collins & Associates (August 1992).

The Facilities Plan and EIS for East Mamala Bay were completed by the City in December 1993.[8] These documents analyzed a variety of alternatives for meeting the needs of the predicted increase in wastewater treatment requirements. The EIS concluded that the preferred alternative, improving the collection system and upgrading the SIWWTP to "advanced" primary treatment, would not have any unmitigable adverse impacts. This advanced treatment alternative included the addition of chemical treatment and other improvements to the primary system.

The purposes of the Mamala Bay Study Commission, as mandated by the consent decree, were to: (1) resolve contention over the adequacy of information on the quality of Mamala Bay waters, using detailed scientific study, and (2) recommend measures to improve water quality. A study fund was created using money from the City.

The scientific studies were begun following the publication of the Final EIS for the East Mamala Bay Facilities Plan. A total of 27 distinct studies, together comprising the Mamala Bay Study (MBS), were commissioned. The components of the MBS were intended to develop a water quality management plan for Mamala Bay and to collectively address the issues set forth in the consent decree. These issues include the impact on Mamala Bay water quality of the City's WWTP effluent discharges and the level of wastewater treatment required at City WWTPs to protect the water quality of Mamala Bay. The studies addressed ocean circulation, characteristics of outfall plumes, sources of point and nonpoint pollution, risks to public health, effects on the Mamala Bay ecosystem, and water quality management alternatives. The final results of the studies were published by the Mamala Bay Study Commission in April of 1996.

The MBS was used as background information for evaluation of cumulative impacts of the action proposed in this EIS (see Section 4.4).

HWWTP - The Facilities Plan and EIS for West Mamala Bay are still under development. No date has currently been set for their completion.

EIS for Hawaii Dredged Material Disposal Sites Designation - Maintenance dredging for harbors in the Hawaiian Islands is performed approximately every five to 10 years (or as needed for Pearl Harbor) to maintain adequate operating depths. Harbor depths are reduced as a result of buildup of materials washed into harbors from littoral sources, surface water runoff, and streams. An EIS for the Hawaii dredging material disposal sites was completed in September 1980.[9] The EIS considered the designations of five deep-ocean sites for the continuing disposal of maintenance dredged materials. The proposed action amended the 1977 interim designation of the USEPA Ocean Dumping Regulations and Criteria by altering the location of three sites, adding two new sites, and making final designations of all five sites, including the South Oahu site, which may be used during the construction of the replacement outfall. The EIS describes impacts from use of the sites for dredged material disposal, which are not significant within imposed disposal guidelines.

[8]Belt Collins & Associates (December 1993a) *East Mamala Bay Wastewater Facilities Plan.* Prepared for the City and County of Honolulu, Department of Wastewater Management; Belt Collins & Associates (December 1993b) *East Mamala Bay Wastewater Facilities Plan Final Environmental Impact Statement.* Prepared for the City and County of Honolulu, Department of Wastewater Management.

[9]U.S. Environmental Protection Agency (September 1980) *Final Environmental Impact Statement (EIS) for Hawaii Dredged Material Disposal Sites Designation.*

1.7 Overview of Wastewater Treatment Plant at Fort Kamehameha

The WWTP at Fort Kamehameha presently discharges sand-filtered and disinfected secondary effluent, or "advanced" secondary effluent, into the Pearl Harbor Entrance Channel. This section provides an overview of the WWTP including its location, operation, and various improvements completed at the plant.

1.7.1 Location and Context

The WWTP at Fort Kamehameha is located on Navy land adjacent to Hickam Air Force Base (AFB), near the entrance to Pearl Harbor in the Ewa district of Oahu. The WWTP is owned, operated, and maintained by PWC and was built in increments beginning in 1969. It occupies approximately 4.7 hectares (12 acres) of land and treats both domestic and industrial wastewater flows generated by the Pearl Harbor Naval Complex and the Hickam Complex (Figure 1.7-1). The Pearl Harbor Naval Complex consists of the Main Naval Complex, Ford Island, Ship Wastewater Collection Ashore Abatement System, the Marine Corps' Camp Smith, and adjacent family housing. Wastewater from a holding tank at the Red Hill Complex is also pumped to the Navy collection system. The Hickam Complex consists of Hickam AFB and the Hawaii Air National Guard. Hickam AFB includes the former Fort Kamehameha Army Reservation.

1.7.2 Plant Operations

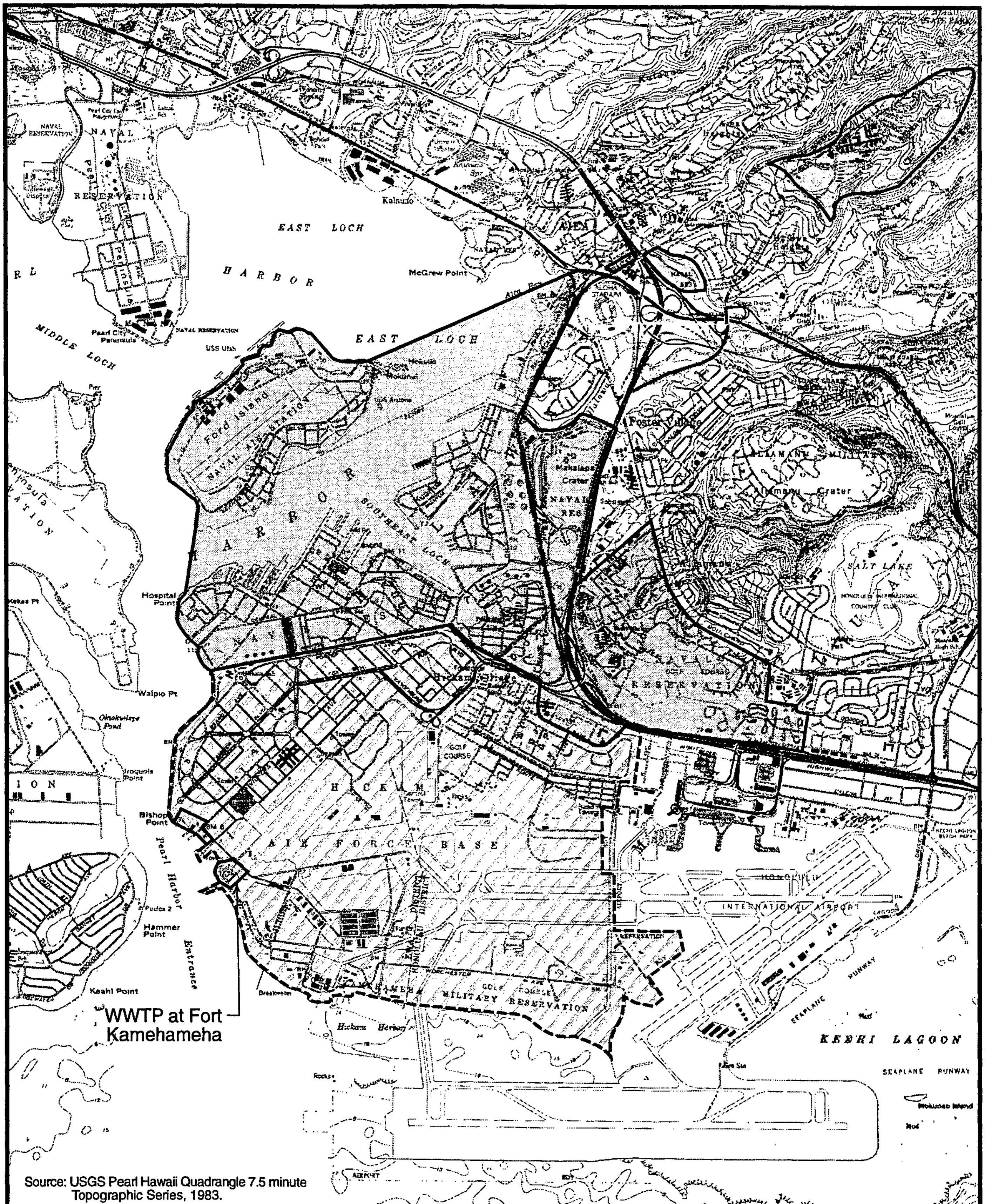
The WWTP provides advanced secondary treatment for wastewater through the use of clarifiers, an activated sludge process, and effluent filtration. The plant's capacity has been expanded from the original design capacity of 28,000 m^3/day (7.4 mgd) to 49,000 m^3/day (13 mgd). The plant includes facilities for the treatment of both liquid and solid waste streams. Recent plant improvements include an anoxic selector process to improve settling of the secondary sludge, sand filters to remove additional particulate matter from the effluent, and ultraviolet (UV) disinfection of effluent prior to discharge.

The treatment processes at the WWTP remove about 90 to 95 percent of the solid and organic matter from the wastewater. The treated wastewater is disinfected by UV light before it is discharged into the Pearl Harbor Entrance Channel through the existing ocean outfall. The existing outfall is a 76-cm (30-inch)-diameter, 549-m (1,800-ft)-long reinforced concrete pipe that discharges the treated wastewater through a diffuser at a depth of 13.7 m (45 ft).

1.7.3 Treatment Processes

The WWTP at Fort Kamehameha treats the wastewater by an activated sludge process followed by sand filtration and UV disinfection. Major unit processes include the following (Figure 1.7-2):

- Headworks to screen raw wastewater,
- Primary clarifiers to remove settleable solids (primary sludge),
- Aeration tanks to aerate and biologically convert suspended and dissolved organic matter to settleable biomass (secondary sludge),
- Aeration/anoxic tanks to control organisms that impede settling in the secondary clarifiers,
- Secondary clarifiers to remove secondary sludge from the treated wastewater,
- Traveling bridge sand filters to further remove particulate matter,



NORTH

0 200 4000
SCALE IN FEET
0 600 1200
SCALE IN METERS 1:48,000

LEGEND

- Navy land serviced by WWTP
- Air Force land serviced by WWTP

Figure 1.7-1
SERVICE AREA OF WWTP AT FORT KAMEHAMEHA
EIS for Outfall Replacement, WWTP at Fort Kamehameha
March 2001

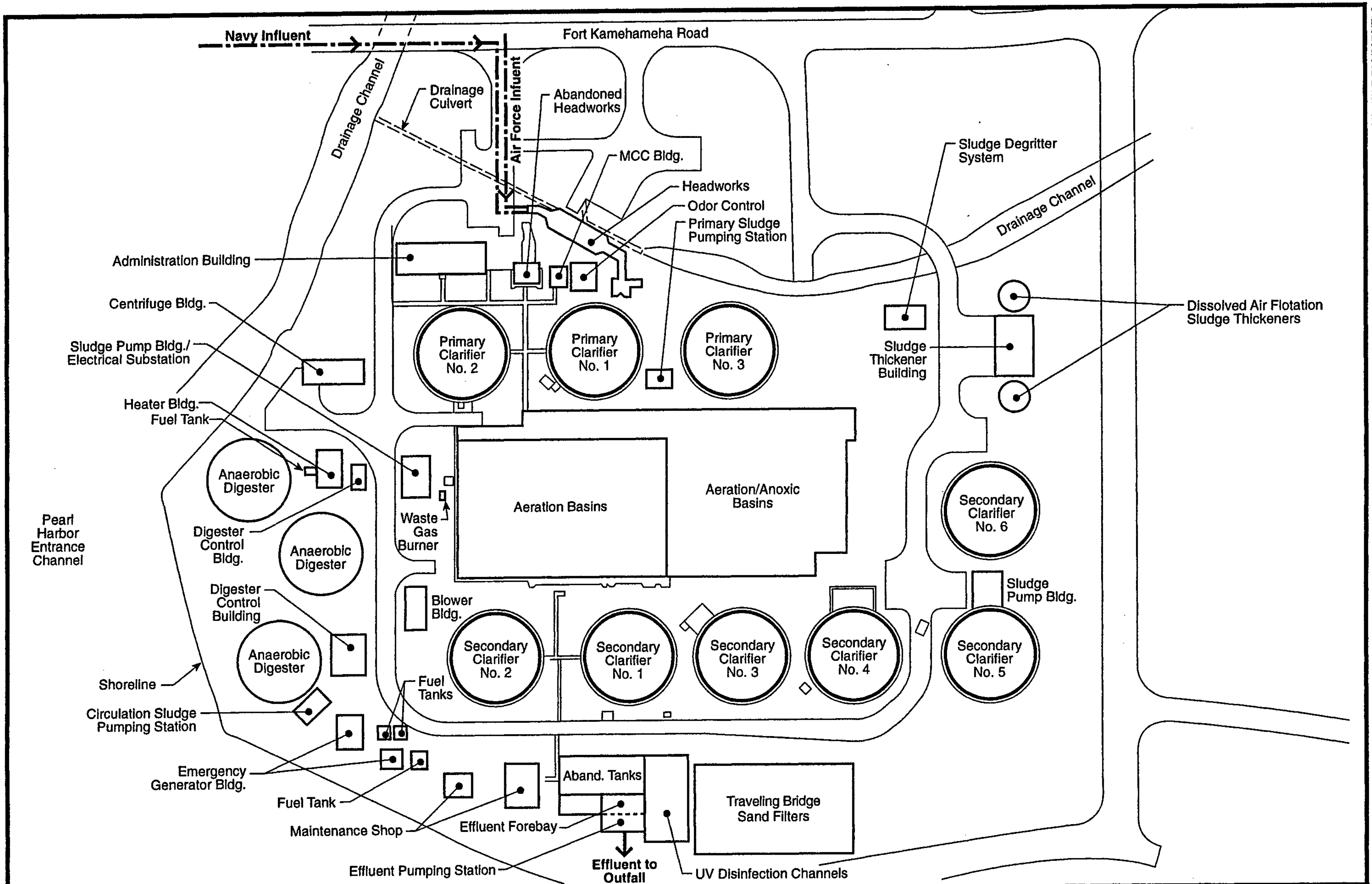


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Figure 1.7-2
EXISTING WWTP SITE LAYOUT

EIS for Outfall Replacement, WWTP at Fort Kamehameha
March 2001

- UV disinfection facilities,
- Dissolved air flotation sludge thickeners,
- Anaerobic digestors to stabilize and condition both primary and secondary sludge prior to dewatering, and
- Centrifuges to reduce water content of the digested and thickened sludge to approximately 80 percent by weight prior to disposal off site.

Collection and Screening Processes. Raw wastewater is transferred from the Pearl Harbor and Hickam complexes via pumping stations and gravity sewers and is combined with various plant sidestream flows in the plant headworks. The combined flows then pass through mechanical bar screens to remove coarse objects.

Primary Clarification. After pretreatment, the wastewater flows by gravity to three primary clarifiers. A large portion of the solids, referred to as primary sludge, is separated and transferred to the solids handling system (see below). Two clarifiers are 24 m (80 ft) in diameter and 2.7 m (9 ft) deep. The third clarifier is 29 m (95 ft) in diameter and 3.7 m (12 ft) deep. The purpose of primary clarification is to concentrate and remove suspended organic solids from wastewater using gravity separation.

The primary clarifiers have rotary sludge rakes and skimmers. The sludge rakes travel over the bottom of the units, while the skimmers travel over the wastewater's surface to remove the sludge and scum, respectively. The scum and sludge collected in the primary clarifiers are then pumped to the solids handling system. Effluent from the primary clarifiers flows by gravity into the primary effluent channel, then to the activated sludge anoxic and aeration basins.

Activated Sludge with Anoxic Selector. The activated sludge process is a suspended-culture system in which settled sludge from the secondary clarifiers is returned to the aeration basins to increase the available biomass (microorganisms). The microorganisms metabolize and biologically flocculate the suspended and dissolved organic material in the wastewater. The anoxic selector improves the secondary sludge settling characteristics by providing anoxic (low dissolved oxygen content) zones at specific stages of the aeration process. These anoxic zones prevent filamentous microorganisms, which impede proper settling of secondary sludge, from growing during the aeration process.

Secondary Clarification. The effluent from the activated sludge aeration basins flows by gravity into six secondary clarifiers where most of the suspended solids settle out, concentrating the biomass. The secondary sludge is collected in these clarifiers by either a rapid sludge removal system or a spiral scraper. Most of the collected sludge is pumped back to the aeration tanks as return sludge. The remaining sludge and secondary scum are pumped to the solids handling system (see below).

Effluent Filtration. Prior to disinfection, the effluent is filtered using multimedia sand filtration to remove suspended solids that are not removed by the secondary clarifiers.

Disinfection. Filtered effluent then flows to the UV disinfection tank, where it is disinfected by exposure to intense UV light prior to discharge.

Disposal. Following disinfection, the effluent generally flows by gravity through the existing ocean outfall and discharges into the ocean. At times of extremely high wastewater flows, coincident with high tides, it is necessary to pump the effluent through the outfall. As part of the recent expansion project, a new effluent pump station was constructed.

Solids Handling System. Sludge from the primary clarifiers is first pumped to a sludge degritter system to remove the inorganic solids and heavier organics which are referred to as grit.[10] After the grit is removed, the primary sludge is pumped with the secondary sludge to two dissolved air flotation sludge thickeners. The thickened sludge is then processed by three anaerobic digestors. The anaerobic digestors convert much of the sludge into liquids or gases, minimizing the residual biomass. The liquids produced are recycled back to the plant headworks while the gases are sent to a flare for burning. The remaining sludge is then dewatered by centrifuges prior to offsite disposal. The liquids produced by the centrifuges are also recycled back to the plant headworks.

Auxiliary Systems. Recently completed improvements to the WWTP include an upgrade of the electrical system and the installation of an odor control system. In addition, a new 1,400 kilowatt emergency generator was added at the southwest corner of the WWTP.

Prior to plant expansion, the quality of the effluent generally met permit requirements but occasionally exceeded permit limits. Although not required within the zone of mixing (ZOM)[11] defined in the NPDES permit for the effluent discharge, the nutrient content of the undiluted effluent generally met the receiving water quality standards for concentrations of ammonium nitrates, total nitrogen, and phosphorous. Occasional exceedences of Pearl Harbor Estuary water quality standards within the existing ZOM result primarily from nonpoint source pollution from land-based sources.

1.8 Document Organization

This EIS is organized in the following manner:

- Chapter 2 - Proposed Action and Alternatives gives details of the proposed action and the alternatives to the proposed action. It provides information regarding the tiered evaluation, or screening process, performed to eliminate those alternatives determined to be infeasible from further analysis.
- Chapter 3 - Regional Environmental Setting describes the current state of the environment in the region potentially impacted by the proposed action and the alternatives.
- Chapter 4 - Analysis of Impacts and Mitigation analyzes the potential impacts of the proposed action and the underground injection and no-action alternatives, identifies where applicable, potential mitigation for these impacts, and provides a summary of environmental consequences with identification of the preferred alternative and the environmentally preferred alternative.

[10]Inorganic solids include pebbles, sand, silt, egg shells, and metal fragments. Heavier organics consist of bone chips, seeds, and coffee and tea grounds.

[11]ZOMs are areas around outfall discharges that are exempt from water quality standards, to allow for the initial dilution of treated effluent.

CHAPTER TWO

PROPOSED ACTION AND ALTERNATIVES

CHAPTER TWO
PROPOSED ACTION AND ALTERNATIVES

2.1 Introduction

This chapter describes the proposed action and alternatives and provides information regarding the tiered evaluation process used to determine the feasible alternatives, whose environmental effects are analyzed in greater detail in Chapter 4.

2.1.1 Organization of Chapter

This chapter begins with an overview of the proposed action and alternatives. An explanation of the methodology used to develop the data that are presented for the proposed action and alternatives follows. The main body of the chapter presents an in-depth description of the proposed action and alternatives, including such information as applicable regulatory constraints, the construction process, operational and maintenance requirements, and life-cycle cost estimates. A preliminary evaluation of the proposed action and alternatives was performed to determine feasibility. The chapter concludes with a summary of the proposed action and alternatives considered for detailed environmental impacts analysis and the results of this analysis.

2.1.2 Overview of the Proposed Action and Alternatives

This section provides an introduction to the proposed action and potentially reasonable alternatives to the proposed action. The proposed action constitutes the preferred alternative.

2.1.2.1 Introduction to the Proposed Action

The proposed action consists of the construction and operation of a new wastewater effluent outfall to replace the existing outfall of the Wastewater Treatment Plant (WWTP) at Fort Kamehameha. The proposed outfall satisfies the project's purpose by eliminating the discharge of wastewater effluent into the Water Quality Limited Segment (WQLS) of Pearl Harbor (see Figure 1.2-1). This is accomplished by relocating the effluent discharge from the Pearl Harbor Estuary to Class A Open Coastal Waters. The Pearl Harbor Estuary is classified by the State Department of Health (DOH) as Class 2 Inland Waters, signifying that the discharge of additional pollutants to the estuary will not be allowed. Although the current WWTP at Fort Kamehameha discharge is authorized by an administrative extension of the expired permit, the new permit, when issued, is expected to contain more stringent effluent requirements for discharge of nutrients and metals to the WQLS of Pearl Harbor. The new requirements are expected to increase to the extent that the existing discharge to Pearl Harbor would likely be noncompliant (see Appendix I).

The WWTP at Fort Kamehameha is currently the only remaining major treatment facility on Oahu discharging to an estuary. By relocating the discharge to Open Coastal Waters, the proposed new outfall will no longer discharge into an estuary or a WQLS. The proactive relocation of the discharge would be in consonance with statewide water quality objectives. The relocated effluent discharge will be into deeper waters, which provide better mixing and dilution than the existing outfall. In these deeper waters, there is a much greater capacity for assimilation of the effluent with only minor impacts to receiving waters, in comparison to the existing outfall. A more detailed

description of these water body classifications and their relevance to the proposed discharge relocation is provided in Chapter 4.

2.1.2.2 Development of the Alternatives and Refinement of the Proposed Action

A tiered approach was used to determine and develop the alternatives to the proposed action. At the first level, consideration was given to alternative methods of effluent disposal other than a replacement outfall.

A potential alternative that was considered and dismissed at this level, because it would be impractical to implement, was pumping the wastewater to the Sand Island Wastewater Treatment Plant (SIWWTP), which is owned and operated by the City and County of Honolulu (City). The SIWWTP is a primary plant that operates under a waiver to the national requirements for secondary treatment of wastewater as defined in Section 301(h) of the Clean Water Act (CWA).

The four major reasons that this potential alternative was found to be impractical to implement are summarized here. First, because a large component of the influent to the WWTP at Fort Kamehameha comes from industrial sources, diverting this wastewater stream to the SIWWTP could potentially result in the City losing its 301(h) waiver in addition to potentially causing problems with permit compliance. The capital and operating costs associated with upgrading the SIWWTP to secondary treatment would be prohibitive.

The second reason is that existing sewer lines are not available to convey the wastewater to the SIWWTP. A new conveyance system, consisting of a large wastewater pump station and a force main approximately 12.9 kilometers (km) (8 miles [mi]) in length, would need to be constructed. The force main would cross three streams and Honolulu Harbor to reach the SIWWTP. The cost of constructing this conveyance system would be very high, and there would also be environmental impacts, such as the potential for encountering archaeological resources and the disruption to traffic and other existing activities while trenching for the force main.

Third, if the wastewater were conveyed to the SIWWTP without any treatment at the WWTP at Fort Kamehameha, additional treatment capacity that has not been anticipated and planned for would need to be provided at the SIWWTP. Furthermore, the capacity of the existing Sand Island outfall is intended to serve existing and future development according to City plans. Even if the wastewater were treated at the existing Fort Kamehameha facility prior to pumping it to the SIWWTP, costly pumping through the outfall or construction of a second outfall would be required sooner than anticipated based on existing plans.

Finally, this potential alternative would not be consistent with the State's existing water management plan, required under Section 208 of the CWA, which states that Navy and Air Force wastewater will be treated and discharged through the WWTP at Fort Kamehameha. Amending this plan so that the wastewater could be diverted to the SIWWTP would be an onerous and very time-consuming process.

Alternatives identified and considered to be potentially practical to implement at the first level included underground injection, no action, treatment plant upgrade, infiltration/evaporation, and effluent reuse. Conceptual designs were developed for analysis of these alternatives. The conceptual designs do not include the same level of detail for all alternatives. The conceptual design process for a particular alternative was carried forward until it became evident that the alternative was not feasible. Specifically, system details and cost estimates were not developed for

the infiltration and evaporation alternative, because the land area required to dispose of the effluent flow was determined to be unavailable. Therefore, this alternative was found to be infeasible without further evaluation. Based upon preliminary analysis of these conceptual designs, treatment plant upgrade, infiltration/evaporation, and effluent reuse were eliminated as impractical alternatives for reasons identified in Section 2.8. Underground injection was determined to be a reasonable alternative to the proposed action. Accordingly, the proposed action, the underground injection alternative, and the no-action alternative were carried forward for a more detailed second-tier analysis of their environmental impacts, presented in Chapter 4.

At the third level, various outfall alignment options and two diffuser options were studied. Development of the proposed action was an iterative design process in which the alignment of the outfall and the proposed construction methods were analyzed and modified several times (see Figure 1.4-1). The alignment originally proposed during the scoping phase was found to pass through a region of very soft marine sediments incapable of adequately supporting the outfall pipe. Several subsequent alignment options were investigated and rejected because they were found to pass through areas of substantial living coral growth. Additional factors considered during the alignment selection process included proximity to the historic Fort Kamehameha housing area and to the two sand islets offshore of the housing area. These islets serve as foraging and resting habitat for various migratory birds, including the endangered Hawaiian stilt.

Two other alignment options located outside of the alignment corridor shown in the Draft Environmental Impact Statement (DEIS) were also considered. An alignment to the east through Hickam Harbor (see Figure 1.4-1) was eliminated from further consideration because it would involve construction of the outfall in submerged lands belonging to the State.

An alignment along the western side of the Pearl Harbor Entrance Channel was eliminated for several reasons. This western alignment would require burying the sewer outfall pipe across the Pearl Harbor Entrance Channel, well below the mudline so that it would not be damaged by ship anchoring emergencies in the channel. Because the proposed outfall is designed for gravity flow, the preferred vertical alignment of the pipe would be to maintain a downward slope. Thus, the pipe would remain deep after crossing under the Pearl Harbor Entrance Channel. Along the western edge of the channel, excavation depths for trenching would average at least 7.6 meters (m) (25 feet [ft]) (assuming a 21.3-m (70-ft)-deep pipe invert and 13.7 m [45-ft] mudline). The bottom material is expected to be quite flat, so the excavation quantities and associated construction costs would increase dramatically compared to the 3.0-m (10-ft)-deep trench along the proposed alignment. The deeper the sewer outfall alignment, the more costly it is to construct. In addition, land-based construction equipment and vehicles could not be used to construct the western alignment, so diver requirements would be greater, adding to the construction costs.

If the outfall was designed to cross under the channel and come back up, an inverted siphon would be created. Although occasionally used in gravity collection systems to cross streams and other obstructions, an inverted siphon is a high maintenance conveyance due to the tendency for solids to settle at the bottom of the siphon. Clean out access points are needed on each side of the siphon. An inverted siphon under the Pearl Harbor Entrance Channel would be much larger than is typical, and access for cleaning and maintenance would be difficult and costly.

An alignment along the western side of the Pearl Harbor Entrance Channel would also encounter areas of living coral. Although a survey has not been performed on the western side of the channel, cursory observations have indicated that coral densities on the western side are similar to or greater than those along the preferred alignment.

The preferred outfall alignment and the specific selection of construction methods along the alignment are a result of extensive geotechnical and benthic investigations and construction methodology analysis. The preferred alignment minimizes environmental impacts to benthic communities, avoids the offshore sand islets and the Fort Kamehameha housing area, and is considered constructable by the proposed methods.

The diffuser options presented during the scoping phase and in the DEIS were also subjected to additional consideration. The diffuser preferred during the scoping phase and proposed in the DEIS was retained. Given its length and depth, it provides superior dilution and a smaller zone of mixing (ZOM) than the longer, shallower diffuser.

2.1.2.3 Introduction to the Alternatives

This section introduces the five alternatives to the replacement outfall that were evaluated at the first tier of this Environmental Impact Statement (EIS) process: underground injection, no action, treatment plant upgrade, infiltration and evaporation, and effluent reuse.

Each alternative was conceptually configured to meet the purpose of the proposed action, which is to reduce mass loadings from the discharge of wastewater effluent into the WQLS of Pearl Harbor Estuary. The alternatives were also conceptually configured to meet the project's needs, which are to provide an effluent disposal system that meets all environmental and regulatory constraints and is similar in capacity and operational reliability to the existing outfall system. Life-cycle costs were then estimated to determine whether the alternative is economically competitive with other disposal options and suitable for acquisition under prevailing federal standards. Alternatives that are infeasible for acquisition are not reasonable.

Underground Injection

Effluent disposal by subsurface injection requires the construction of a sufficient number of injection wells in the vicinity of the WWTP to dispose of the projected future flow of 49,000 cubic meters per day (m^3/day) (13 million gallons per day [mgd]). This method of disposal is highly dependent upon the existence of suitable subsurface geologic conditions for effluent injection.

No Action

This alternative is continued use of the existing outfall indefinitely into the future. The existing outfall discharges into 14-m (46-ft)-deep water in the Pearl Harbor Entrance Channel adjacent to the WWTP at Fort Kamehameha (see Figure 1.4-1). As noted earlier, it is anticipated that more stringent limits for discharge of nutrients and toxins to the estuary will be imposed by the DOH at the next permit renewal. The U.S. Environmental Protection Agency (USEPA) has indicated that these anticipated limits may be exceeded unless action is taken to reduce these loadings (see Appendix I). Additional costly treatment, which is not practical, would be necessary at the WWTP (see Treatment Plant Upgrade). Taking no action jeopardizes the ability of Navy Public Works Center, Pearl Harbor (PWC) to meet anticipated near term permit requirements and to treat and dispose of increased future wastewater flows.

Treatment Plant Upgrade

This potential alternative includes the addition of nutrient removal facilities and possibly toxin removal facilities to the WWTP to satisfy the requirements for discharge of anticipated increased future flows to the Pearl Harbor Estuary. Removal of both nitrogen and phosphorous could be accomplished by a biological nutrient removal system. Removal of toxic constituents, specifically heavy metals and pesticides, could be accomplished by granular activated carbon (GAC) filtration of the effluent prior to disinfection. Based upon identified constraints for this alternative, including estimated land requirements and life-cycle costs of the proposed facilities, presented in Section 2.5, this alternative is not considered reasonable. Thus, this alternative is rejected and the specific environmental impacts of this alternative are not analyzed in subsequent chapters of this EIS.

Infiltration and Evaporation

Effluent disposal by infiltration and evaporation requires the construction of very large infiltration/evaporation ponds, from which the effluent would simultaneously evaporate and infiltrate into the ground. The detailed analysis of this option, provided in Section 2.6, indicates that more than 105 hectares (ha) (260 acres [ac]) would be required to dispose of the projected future flow of 49,000 m^3/day (13 mgd). Based on this large land requirement, this alternative is not considered reasonable. Therefore, the infiltration and evaporation alternative is rejected, and the specific environmental impacts are not analyzed in subsequent chapters of this EIS.

Effluent Reuse

The philosophy behind wastewater effluent reuse is somewhat different from that of effluent disposal. Although reusing effluent functionally disposes of it, the focus is on the benefits that are obtained from reusing the effluent. The effluent is seen as a resource rather than a waste material to be disposed. Because effluent reuse not only provides a resource but also disposes of a continually produced flow of treated wastewater, the economics of reuse are dependent upon the cost of converting the waste to a usable resource and upon demand for the resulting product. The effluent must meet the requirements of users and must be available at a price comparable to other sources of nonpotable water.

The primary demand for nonpotable water in the vicinity of the WWTP at Fort Kamehameha is for irrigation of golf courses and landscaped areas at the Honolulu International Airport. There is also a nonpotable water demand for aircraft wash down at the airport. Because of the high salinity of the effluent from the WWTP at Fort Kamehameha, there is no apparent reuse potential without first desalinating the effluent. The chloride content, a common measure of salinity, ranges from 3,500 milligrams per liter (mg/l) to 5,500 mg/l.[1] Desalinated effluent could be distributed to reuse areas in the vicinity of the WWTP, including golf courses within approximately 5 km (3 mi) and the Honolulu International Airport. Brine produced from the desalination process would contain nutrients and other constituents of the wastewater effluent and would need to be disposed to injection wells. DOH regulations require adequate effluent storage or a backup disposal system for times when the effluent flow rate exceeds the reuse requirements. Backup disposal would be provided by the existing outfall and the proposed brine-disposal injection wells.

Based upon identified constraints for this alternative, including high life-cycle costs for production of usable nonpotable water and insufficient demand for reuse of the effluent at its production cost,

[1]U.S. Navy, Pacific Division, Naval Facilities Engineering Command (1996) *Monthly Summaries of Daily Effluent at the WWTP at Fort Kamehameha, Pearl Harbor, Hawaii.*

presented in Section 2.7, this alternative is not considered reasonable. This alternative is rejected, and the specific environmental impacts of this alternative are not analyzed in subsequent chapters of this EIS.

2.1.3 Applicable Regulations

Table 2.1-1 summarizes the federal and state regulations applicable to the discharges from the proposed action and each alternative. Table 2.1-2 summarizes the Executive Orders applicable to the proposed action and alternatives. Executive Order 13045, *Protection of Children from Environmental Health Risks and Safety Risks*, was considered but determined to be inapplicable to the proposed action and alternatives.

2.1.4 Methodology

This section describes the methods used to develop comparable information on the proposed action and each alternative.

Planning and Design Assumptions

For each alternative, a "model" system was developed that would dispose of 49,000 m^3/day (13 mgd) of effluent. This flow rate is based on the existing design capacity of the upgraded WWTP. Except for the no-action alternative, the models comply with all applicable federal, state, and local regulations, as well as with relevant engineering and environmental standards for construction and operation. This approach makes the alternatives, except for no action, equivalent from a compliance standpoint. The next section describes the methods used to develop cost estimates for the proposed action and each alternative.

Development of Cost Estimates

To enable an economic comparison of the proposed action and alternatives, each was assessed in terms of a 30-year life-cycle cost. Costs include capital outlays and recurring operations and maintenance (O&M) costs. Costs common to all alternatives, such as O&M costs for the existing wastewater treatment process, were excluded from consideration. As identified below, a number of assumptions were made for the purposes of determining costs.

<u>Facility Site and Easement Availability</u>

It was assumed that land and easements for necessary treatment and transmission facilities would be available at no cost. Where practical, new transmission lines were routed along existing roads.

<u>Capital Costs</u>

The capital cost estimate for the proposed action was based upon a Parametric Cost Estimate prepared for Pacific Division, Naval Facilities Engineering Command (PACNAVFACENGCOM) by engineering consultants.[2] Estimates of capital costs for the alternatives were based upon the U.S. Navy *Cost Data Book*,[3] conversations with equipment vendors and manufacturers, consultant

[2]U.S. Navy, Navy Public Works Center (June 2, 1997) *FY 1999 Military Construction Project Data (Form DD1391) Project Number P-497, Sewer Outfall Extension, Wastewater Treatment Plant at Fort Kamehameha.*
[3]U.S. Navy, Pacific Division, Naval Facilities Engineering Command (April 1993) *Cost Data Book.*

Table 2.1-1
Regulations Applicable to Discharges from the Proposed Action and Alternatives

Disposal Method	Statute	Federal		State	
		Regulation	Requirement	Regulation	Requirement
Replacement Outfall (Proposed Action)	Clean Water Act, Section 402	40 CFR[1] 122, National Pollutant Discharge Elimination System Permit Regulations	- Control point-source discharges from the outfall	HAR[2] 11-55, "Water Pollution Control" HAR 11-54, "Water Quality Standards"	- Control point source discharges from the outfall - Control discharges to surface waters associated with construction activity dewatering and hydrotesting
	Clean Water Act, Section 401	None	None	HAR 11-54, "Water Quality Standards"	- Certification from the state in which the discharge will originate that any such discharge will comply with applicable provisions of the Clean Water Act
	Clean Water Act, Section 404 Marine Protection, Research, and Sanctuaries Act, Section 103 Rivers and Harbors Act, Section 10 Water Resources Development Act, Section 506	40 CFR 220-227, USEPA Ocean Dumping Regulations 33 CFR 320-330 and 40 CFR 230-232, Regulatory Programs of the Corps of Engineers	- Determine suitability of dredged material for ocean disposal - Control impacts on navigable waters of the U.S. - Ensure that the dredged material disposal option is the least damaging to the aquatic ecosystem (i.e., the most practicable option taking technology, logistics, and cost into consideration)	None	None

Table 2.1-1 *(continued)*

Disposal Method	Statute	Federal		State	
		Regulation	Requirement	Regulation	Requirement
Underground Injection	Clean Water Act, Section 404	33 CFR 320-330 and 40 CFR 230-232, Regulatory Programs of the Corps of Engineers	- Minimize impacts to wetland areas	None	None
	Safe Drinking Water Act	40 CFR 144-148, Underground Injection Control 40 CFR 149, Sole Source Aquifers	- Establishes minimum requirements for state UIC programs - Establishes criteria for identifying critical aquifer protection areas	HAR 11-23, "Underground Injection Control" (UIC)	- Disposal only below "UIC line" - Well design standards - Record-keeping and reporting - Establishes criteria for exempting aquifers from underground source of drinking water status
Existing Outfall (No Action)	Clean Water Act, Section 402	40 CFR 122, National Pollutant Discharge Elimination System Permit Regulations	- Control point-source discharges from the outfall	HAR 11-55, "Water Pollution Control" HAR 11-54, "Water Quality Standards"	- Control point source discharges from the outfall
	Rivers and Harbors Act, Section 10	33 CFR 320-330 and 40 CFR 230-232, Regulatory Programs of the Corps of Engineers	- Minimize impacts to navigable waters of the U.S.	None	None
Treatment Plant Upgrade	Clean Water Act, Section 402	40 CFR 122, National Pollutant Discharge Elimination System Permit Regulations	- Control point-source discharges from the outfall - Control storm water discharges associated with construction activities	HAR 11-55, "Water Pollution Control" HAR 11-54, "Water Quality Standards"	- Control point source discharges from the outfall - Control storm water discharges associated with construction activities if area of disturbance is greater than 5 ac

Table 2.1-1 *(continued)*

Disposal Method	Statute	Federal		State	
		Regulation	Requirement	Regulation	Requirement
Treatment Plant Upgrade *(continued)*	Rivers and Harbors Act, Section 10	33 CFR 320-330 and 40 CFR 230-232, Regulatory Programs of the Corps of Engineers	- Minimize impacts to navigable waters of the U.S.	None	None
Infiltration and Evaporation	Clean Water Act	None	None	HAR 11-62, "Wastewater Systems"*	- DOH approval of wastewater disposal system required
Effluent Reuse	Clean Water Act	None	None	HAR 11-62, "Wastewater Systems"*	- Control public access - Mark piping and appurtenances - Provide adequate effluent storage capacity or back-up disposal
	Safe Drinking Water Act	None	None	DOH "Guidelines for the Treatment and Use of Reclaimed Water"	- Treat to required level - Isolate and mark transmission and distribution systems - Continuous effluent monitoring - Quarterly groundwater monitoring - Public awareness signs and markings - Employee education programs
				HAR 11-23 "UIC"	(Brine disposal, same as UIC for Underground Injection)

[1] CFR = Code of Federal Regulations
[2] HAR = Hawaii Administrative Rules
* Applicable only on nonfederal lands

Table 2.1-2
Applicable Executive Orders

Executive Order No.	Title	Date	Description	Applicable to					
				Replacement Outfall	Underground Injection	No Action	Treatment Plant Upgrade	Infiltration and Evaporation	Effluent Reuse
11988	Floodplain Management	May 24, 1977	Provides floodplain management direction for federal agencies for avoiding to the extent possible the long-term and short-term adverse impacts of occupying and modifying floodplains, and for avoiding direct and indirect support of floodplain development whenever this is practical.	No	Yes	Yes	Yes	Possibly - depends on site location	Yes
11990	Protection of Wetlands	May 24, 1977	Directs federal agencies to avoid long-term and short-term adverse impacts associated with the destruction or modification of wetlands, and to avoid direct or indirect support of new construction in wetlands.	Possibly - depends on siting of construction staging areas	Yes	No	Possibly - depends on site location	Possibly - depends on site location	Possibly - depends on site location

Table 2.1-2 *(continued)*

Executive Order No.	Title	Date	Description	Applicable to					
				Replacement Outfall	Underground Injection	No Action	Treatment Plant Upgrade	Infiltration and Evaporation	Effluent Reuse
12898	Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations	February 11, 1994	Requires federal agencies to identify and address, as appropriate, the potential for disproportionately high and adverse environmental effects of its actions on minority and low-income populations. Specifically, government agencies must analyze human health, economic, and social effects on minority and low-income communities and ensure that, whenever feasible, mitigation measures address significant and adverse effects of proposed federal actions on such communities. The government is also charged with providing opportunities for community input during the National Environmental Policy Act process, and ensuring that minority and low-income communities have adequate access to public information on the relevant issues.	Yes	Yes	Yes	Yes	Yes	Yes

Table 2.1-2 *(continued)*

Executive Order No.	Title	Date	Description	Applicable to					
				Replacement Outfall	Underground Injection	No Action	Treatment Plant Upgrade	Infiltration and Evaporation	Effluent Reuse
13089	Coral Reef Protection	June 11, 1998	Requires federal agencies to identify actions that may affect U.S. coral reef ecosystems, protect and enhance the conditions of coral reef ecosystems, and ensure that the actions they authorize, fund, or execute will not degrade the conditions of the coral reef ecosystems. Federal agencies whose actions affect U.S. coral reef ecosystems shall, subject to the availability of appropriations, provide for implementation of measures needed to research, monitor, manage, and restore affected ecosystems, including but not limited to measures reducing impacts from pollution, sedimentation, and fishing.	Yes	Possibly - subsurface flow of effluent to marine environment could impact aquatic habitat	Possibly - increased effluent discharge could impact aquatic habitat	Possibly - increased effluent discharge could impact aquatic habitat	Possibly - depends on degree of additional treatment attained as a result of the disposal method and subsurface flow of effluent to marine environment	Possibly - subsurface flow of brine and/or excess effluent to marine environment could impact aquatic habitat
13186	Responsibilities of Federal Agencies to Protect Migratory Birds	January 10, 2001	Requires federal agencies taking actions that have, or are likely to have, a measurable negative effect on migratory bird populations to develop and implement a Memorandum of Understanding with the U.S. Fish and Wildlife Service that shall promote the conservation of migratory bird populations.	Possibly - depends on location of construction activities	Possibly - depends on location of construction activities	No	Possibly - depends on location of construction activities	Possibly - depends on location of construction activities	Possibly - depends on location of construction activities

experience with project costs, City Board of Water Supply (BWS) and the Department of Wastewater Management (DWM),[4] and PWC experience. Capital costs were adjusted to an FY 1998 basis. All future costs associated with each alternative, including planning, permitting, and design costs, where appropriate, were included. Right-of-way costs were not included because most facilities for the alternatives are on Navy or Air Force land and it was assumed that standard real estate transactions between two federal agencies would be used to develop right-of-way agreements. For facilities on state-owned land, costs of right-of-way acquisitions were not included, as the areas are relatively small.

<u>O&M Costs</u>

Power costs were based on current Hawaiian Electric Company, Inc. (HECO) rates. Either HECO Schedule J for General Service Demand or HECO Schedule P for Large Power Demand were used, whichever yielded the lowest net power cost. Other O&M costs were based on PWC cost experience, discussions with equipment manufacturers, and BWS and DWM experience. Maintenance and other costs were adjusted to an FY 1998 basis.

<u>30-Year Life-cycle Costs</u>

To enable a comparison between the alternatives, a 30-year life-cycle cost was calculated for each. The life-cycle cost includes initial capital (construction) costs plus the present worth of 30 years of annual O&M expenses. In calculating the present worth of O&M expenses, a discount rate of six percent was used.

For the reuse alternative, O&M costs and 30-year life-cycle costs were reduced to account for projected revenue from sale of the reclaimed water at the current rate for nonpotable water.

All costs presented herein are planning level cost estimates, developed for comparison purposes only, and are not intended for project budgeting.

2.2 Replacement Outfall (Proposed Action)

This section discusses in detail the proposed action, which is the construction and operation of a replacement outfall to provide for improved ocean disposal of the effluent from the WWTP at Fort Kamehameha. The existing outfall will be retained for backup (emergency) use.

2.2.1 Receiving Environment

The proposed outfall will discharge treated effluent from the WWTP at Fort Kamehameha into Open Coastal Waters, as defined by the DOH, to the south and east of the Pearl Harbor Entrance Channel (see Figure 1.2-1). As indicated by Figure 1.6-1, the outfall will be located in the coastal waters of Mamala Bay, which encompasses the southern shore of Oahu from Diamond Head to Barbers Point.

2.2.2 Regulatory Constraints and Requirements

This section identifies the permits and other regulatory limitations and requirements relevant to the proposed action.

[4]This information was acquired prior to 1998 reorganization of City departments, which eliminated the DWM.

2.2.2.1 Aquatic Environment

Section 402 of the CWA, National Pollutant Discharge Elimination System (NPDES) individual permit requirements, is the basis for the expired permit (No. HI 0110086) which authorizes the existing discharge by an administrative extension. The limits of the revised permit are expected to become more stringent if the discharge remains in the WQLS of Pearl Harbor Estuary, and to result in noncompliance for the existing discharge (see Section 2.1.2.1 and Appendix I). All other rules or regulations apply to the construction phase.

A Department of the Army (DA) permit will be required from the U.S. Army Corps of Engineers (USACE) under Section 404 of the CWA and Section 10 of the Rivers and Harbors Act. The DA permit will also be required to satisfy Section 103 of the Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA), if dredged material is to be transported and disposed at the USEPA-designated South Oahu Ocean Dredged Material Disposal Site (ODMDS).

Compliance with other laws is required in conjunction with the DA permit. Those applicable to the project, discussed elsewhere in Section 2.2.2, include the Coastal Zone Management (CZM) Act, Endangered Species Act (ESA), National Historic Preservation Act (NHPA), and Marine Mammal Protection Act.

Clean Water Act

The CWA sections applicable to the proposed action are summarized below.

<u>Section 401 Water Quality Certification</u>

The CWA and Hawaii Revised Statutes Chapter 342D, along with their implementing rules (33 Code of Federal Regulations [CFR], 320 through 330, and Hawaii Administrative Rules [HAR] Title 11, Chapter 54), require that a Section 401 Water Quality Certification be obtained to support federal permits or approvals (e.g., Section 404 permit from the USACE) for which proposed construction or operation may result in discharges to navigable and/or state waters. Applications must be filed with the Clean Water Branch of the DOH at least 180 days before the date the Water Quality Certification is needed. A Section 401 Water Quality Certification will be required for this project.

<u>Section 402 NPDES Permit (Individual and General)</u>

Discharge of pollutants into surface waters of the U.S. are regulated under the NPDES program, pursuant to Section 402 of the CWA. This program is administered by the State of Hawaii DOH under HAR Title 11, Chapter 55, Water Pollution Control (September 22, 1997). This chapter requires submittal of an NPDES application or a Notice of Intent (NOI) for NPDES general permit coverage for the following actions:

- Discharge of pollutants,
- Substantial alteration of the quality of discharge, and
- Substantial increase of the quantity of discharge.

Two State NPDES general permits may apply to the project. These include a general permit for discharges to surface waters associated with construction activity dewatering and for discharges associated with hydrotesting. Surface water discharge of dewatering effluent may be required during trench excavation for the land portion of the outfall. Discharges of hydrotesting effluent are

expected when the new pipe integrity is being tested. NOIs for discharge of excavation dewatering effluent and for discharge of hydrotesting water should be filed separately. A dewatering plan, a plan for treating hydrotesting effluent, and Best Management Practices (BMP) plans would be required. The development and implementation of these plans would be part of the permitting and compliance processes for NPDES general permit coverage.

An NPDES permit for storm water discharges associated with construction activities will not be required for construction of the proposed outfall. This coverage is only required if the total area to be disturbed exceeds 2.02 ha (5 ac). Although the total staging area for the proposed project will be approximately 3.0 ha (7.5 ac), only approximately 1.6 ha (4 ac) is unpaved and subject to being disturbed.

During operation of the proposed outfall, the discharge of pollutants will be regulated by an NPDES permit. Monitoring requirements will be developed in cooperation with the DOH, Clean Water Branch, during the discharge permit process under HAR Chapter 11-55. The permit must be granted prior to operation of the proposed outfall.

<u>Section 404 CWA Discharge of Dredged or Fill Material into Navigable Waters of the U.S.</u>

Section 404 of the CWA authorizes the Secretary of the Army to issue permits for the discharge of dredged or fill material into navigable waters at a specified disposal site. A permit for such work must be obtained through the USACE in the form of a DA permit. Because the proposed action will result in the discharge of excavated material into navigable waters of the U.S., it will be subject to the provisions and permit requirements set forth in Section 404. Impacts addressed by these provisions and permit requirements include the effects of turbidity and the potential for damage to living corals and other benthic organisms. A DA permit will be obtained for this project.

Marine Protection, Research, and Sanctuaries Act

The MPRSA regulates ocean dumping activities. Section 103 of the MPRSA authorizes the Secretary of the Army to issue permits for the transportation of dredged material for the purpose of disposal into ocean waters. Ocean disposal at the USEPA-designated South Oahu ODMDS of material excavated for outfall construction is contingent upon the USACE's determination that the material is suitable for ocean disposal (i.e., it would not adversely affect the marine environment, ecological systems, economic potentialities, or human health, welfare, or amenities). This determination requires concurrence of the USEPA. Provisions to prevent impacts on the marine environment will be incorporated into the DA permit.

Water Resources and Development Act

Section 506 of the Water Resources and Development Act of 1992 amends Section 102(c) of the MPRSA and requires, in part, that a site management plan be developed for each designated ocean disposal site. A site management plan is required to include: (1) a baseline assessment of conditions at the site; (2) special management conditions or practices to be implemented at the site that are necessary for protection of the environment; (3) consideration of the quantity of the material to be disposed of at site, and the presence, nature, and bioavailability of the contaminants in the material; (4) a program for monitoring the site; (5) consideration of the anticipated use of the site over the long term, including any need for management of the site after the closure; and (6) a schedule for review and revision of the plan. A site management plan for the South Oahu ODMDS is in place.

Rivers and Harbors Act

Section 10 of the Rivers and Harbors Act of 1899 prohibits the obstruction or alteration of navigable waters of the U.S. and alterations or modifications of the course, location, condition, or capacity of any port, harbor or refuge, or enclosure within the limits of any breakwater or of the channel of any navigable water. Under this statute, work or structures affecting navigable waters of the U.S. are permitted if it is recommended by the Chief of Engineers and authorized by the Secretary of the Army. A DA permit will be required for the new outfall structure and for construction activity (including barges and other floating equipment that would be located in the channel during construction).

Underground Injection Control Permit

Dewatering effluent from construction activity may be discharged into underground injection wells. Such a discharge would require a permit under HAR, Title 11, Chapter 23, "Underground Injection Control" (UIC). This program allows wells to be used for discharge of dewatering effluent not containing gross contamination. Specific well siting, water quality testing, and well abandonment procedures would be required by the permit.

2.2.2.2 Navigation

U.S. Coast Guard

Construction of the proposed outfall pipeline in the Pearl Harbor Entrance Channel will require use of barges and heavy equipment that may constitute a navigational obstruction. Therefore, a Notice to Mariners will be required. The U.S. Coast Guard (USCG) publishes a local notice to mariners on a weekly basis warning of all obstructions and potential hazards to maritime navigation.

A written notification must be submitted to the USCG 14 to 21 days prior to commencement of work. The notification must include: (1) a chart of the affected dredging area; (2) identification and size of vessels involved; (3) contact persons, radio frequencies, and phone numbers; and (4) hours of operation and the dates and time period of construction.

All barges and floating equipment will have to be marked and lighted, as approved by the Commander, 14th Coast Guard District, in compliance with Part 118 of Title 33, CFR.

Federal Aviation Administration

Outfall construction could potentially impact the flight line of Honolulu International Airport's Reef Runway 8R. At the location where the proposed outfall alignment crosses under this flight line, the bottom of the flight line is at an elevation of approximately 30 m (100 ft). Any equipment that extends more than 30 m (100 ft) above mean sea level (msl) could interfere with air traffic. In addition, any construction activity near an airport is subject to Federal Aviation Administration (FAA) requirements. A Notice of Proposed Construction (permit number 7460-1) must be obtained from the FAA's Western Pacific Region prior to commencement of construction. The FAA will distribute a Notice to Airmen (NOTAM) warning to aircraft.

2.2.2.3 Protected Species and Habitats

Endangered Species Act

The ESA of 1973 requires proposed actions not to jeopardize the continued existence of federally listed (endangered or threatened) plant and animal species. The only protected species known to inhabit or occasionally visit the project area are the threatened green sea turtle and the endangered Hawaiian stilt. The U.S. Fish and Wildlife Service (USFWS) has jurisdiction over endangered and threatened terrestrial flora, terrestrial fauna, and birds. The National Marine Fisheries Service (NMFS) has jurisdiction over threatened and endangered species that are exclusively marine. For listed species found in both marine and terrestrial habitats, such as sea turtles, the two agencies share responsibility for protection and enforcement. The only protected species of concern under the proposed action that come under joint jurisdiction of both agencies is the green sea turtle.

Under Section 7 of the ESA, federal agencies are required to consult with the USFWS, NMFS, or both, on any action that may affect an endangered or threatened species or results in the destruction or adverse modification of critical habitat designated for such species. Informal Section 7 consultations with USFWS and NMFS were completed in 1997. Both agencies concurred that it is not likely that any listed species or designated critical habitat would be detrimentally affected by the construction and operation of the proposed outfall (see Appendix II-m).

In October 1998, two objects suspected of being ordnance items were observed during a marine benthic survey. A survey of the outfall alignment for ordnance items was then conducted in March and April 1999. During this survey, one projectile was observed in the channel adjacent to the reef flat where water depths range from 7.6 to 17.1 m (26 to 56 ft), and five projectiles were observed at the diffuser end of the outfall. Although it was determined by Navy Explosive Ordnance Disposal (EOD) personnel that all of the projectiles were safe to move and were, in fact, subsequently removed from the site, there is potential for additional ordnance items to be encountered during the construction of the outfall. Because the disposal of any ordnance item might have required detonation in place, which could have adversely affected green sea turtles in the area, formal Section 7 consultation with NMFS was initiated in December 1999. However, the Navy has decided that an engineering solution, involving minor outfall realignment to avoid disturbance of ordnance items, will be implemented, in the unlikely event that one or more ordnance items are detected within the established construction corridor that cannot be picked up and carried away (see Section 2.2.4.6). This engineering solution will not create additional impacts to the environment. Thus, the need for in-place detonation of ordnance is not anticipated and formal Section 7 consultation is not necessary. If it becomes apparent during project execution that in-place detonation of ordnance cannot be avoided, the Navy will reinitiate formal Section 7 consultation with NMFS prior to continuing construction.

Magnuson-Stevens Act/Sustainable Fisheries Act

The Magnuson Fishery Conservation and Management Act (Magnuson Act) of 1976 established a system to more effectively manage and utilize marine fishery resources in the United States. The act was amended in 1986 and 1996. The 1996 amendments provided additional habitat protection. The re-named Magnuson-Stevens Act (16 U.S.C. 1855(b)) calls for direct action to stop or reverse the loss of marine fish habitat. These 1996 amendments were implemented through the Sustainable Fisheries Act (Public Law 104-297) and require the identification of habitats essential to managed species. Identified habitats must be conserved or enhanced. The Regional Fishery Management Councils, in conjunction with the NMFS, perform this work.

The Magnuson-Stevens Act defines Essential Fish Habitat (EFH) as "...those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." Habitat Areas of Particular Concern (HAPC) are areas within EFH, which are deemed to be particularly important or sensitive.

Federal agencies are required to consult with the NMFS on actions, or proposed actions, permitted, funded, or undertaken by the agency that may adversely affect EFH. Only species managed under a federal Fishery Management Plan (FMP) are covered. The Hawaiian Islands are under the jurisdiction of the Western Pacific Regional Fishery Management Council (WPRFMC). The WPRFMC has finalized and issued four amended FMPs, which designate EFH and HAPC for 62 species. The proposed action is not expected to impact any designated EFH or HAPC. In a letter dated November 19, 1999, NMFS concurred that the proposed action is not likely to adversely affect any EFH within or adjacent to the project area. Correspondence pertinent to the EFH consultation is provided in Appendix II-m.

Marine Mammal Protection Act

Marine mammals and their habitat are protected under the Marine Mammal Protection Act of 1972. Under this Act, it is unlawful to harass, hunt, capture, or kill marine mammals, and to import marine mammals or marine mammal products without a permit from either the Secretary of the Interior or the Secretary of Commerce, depending on the species of the marine mammal involved. Such permits may be issued only for purposes of scientific research and for public display if the purpose is consistent with the policies of the Act. No harm to marine mammals or their habitat is anticipated as a result of the proposed action.

Coral Reef Protection

Under Executive Order 13089, *Coral Reef Protection*, dated June 11, 1998, federal agencies are required to identify their actions that may affect U.S. coral reef ecosystems, protect and enhance the conditions of coral reef ecosystems, and to the extent permitted by law, ensure that actions they authorize, fund, or carry out will not degrade the conditions of coral reef ecosystems. It is Navy policy to comply with Executive Order 13089 and to emphasize special considerations for coral reef protection and associated mitigation measures in the final environmental documentation of cases where significant adverse impact is likely.[5] In order to comply with this Executive Order, the alignment of the proposed outfall has been designed to avoid existing coral communities to the maximum extent practicable. Although it is not always possible to avoid coral entirely, the impacts upon the reef ecosystem are minimized by the selected outfall alignment and appropriate construction methods.

Protection of Migratory Birds

Executive Order 13186, *Responsibilities of Federal Agencies to Protect Migratory Birds*, dated January 10, 2001, requires federal agencies taking actions that have, or are likely to have, a measurable negative effect on migratory bird populations to develop and implement a Memorandum of Understanding with the USFWS that promotes the conservation of migratory bird populations. Construction activities for the proposed action have the potential to impact migratory birds that frequent the project area. The outfall alignment has been designed to avoid areas where migratory birds are known to rest and forage.

[5]Department of the Navy letter number 5090, Ser N45D/80589139, dated December 4,1998, from Chief of Naval Operations regarding Coral Reef Protection Policy.

Protection of Wetlands

Executive Order 11990, *Protection of Wetlands*, dated May 24, 1977, directs federal agencies to avoid long-term and short-term adverse impacts associated with the destruction or modification of wetlands and to avoid direct or indirect support of new construction in wetlands. Construction activities for the proposed action have the potential to damage wetland areas. Construction staging areas have been delineated to avoid designated wetland areas.

2.2.2.4 Cultural Resources

National Historic Preservation Act

The project is being carried out in accordance with Section 106 of the NHPA of 1966, as amended, and 36 CFR 800 (implementing regulations). Section 106 requires federal agencies to consider the effects of their actions on historic properties and provide the Advisory Council on Historic Preservation a reasonable opportunity to comment. Section 106 applies to those properties listed in the National Register of Historic Places, as well as to properties that meet specified eligibility criteria, as defined in 36 CFR 60.4. The Navy consulted with the State Historic Preservation Officer (SHPO) in the Department of Land and Natural Resources (DLNR) as it developed means to avoid, reduce, or mitigate any potentially detrimental effects. In a letter dated January 6, 1998, the SHPO concurred with the Navy's determination that the proposed project will have "no effect" on historic properties (see Appendix II-m).

Native American Graves Protection and Repatriation Act

The project is being conducted in compliance with the Native American Graves Protection and Repatriation Act (NAGPRA). Signed into law in 1990, NAGPRA is intended to protect Native American (including Native Hawaiian) graves. The Act also provides for the inventory and repatriation of Native American human remains and associated funerary objects and addresses the conditions and circumstances when Intentional Excavation and Removal of Native American Human Remains and Objects is permitted. Regulations providing procedures are found at 43 CFR 10.3. If Hawaiian burials are encountered, NAGPRA requires consultation with appropriate Native Hawaiian organizations, such as the Office of Hawaiian Affairs and Hui Malama I Na Kupuna O Hawaii Nei. The Oahu Burial Council within the DLNR may also be consulted. It is unlikely that the proposed action will impact Hawaiian burials.

2.2.2.5 Coastal Zone Management

The Hawaii CZM program, which has been approved by the U.S. Department of Commerce, is administered by the Department of Business, Economic Development and Tourism (DBEDT). Under the law, federal actions that are reasonably likely to affect any land or water use or natural resource of the coastal zone must be consistent with the state's CZM program. The "coastal zone" in Hawaii encompasses all lands and waters, except for areas under federal ownership or exclusive control. Although the proposed action is located entirely within federal property, the potential exists for spillover effects to impact nonfederal areas. Therefore, a consistency determination was filed in compliance with the National Coastal Zone Management Act of 1972 (Public Law 92-583), as amended. The response from DBEDT and Navy's reply letter are provided in Appendix II-m. The proposed action is consistent with the state's CZM program.

2.2.2.6 Socioeconomics

Environmental Justice for Minority and Low-Income Populations

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, issued February 11, 1994, requires federal agencies to identify and address, as appropriate, the potential for disproportionately high and adverse environmental effects of their actions on minority and low-income populations. The proposed action will not disproportionately affect either minority or low-income populations.

2.2.3 Physical Description of the Proposed Outfall

The proposed outfall will be a 107-centimeter (cm) (42-inch)-diameter pipe, extending 3.9 km (2.4 mi) from the WWTP effluent pump station to a depth of 46 m (150 ft), where it will terminate in a 200-m (656-ft)-long diffuser. The preferred alignment for construction of the new outfall is shown in Figure 2.2-1.

For a diffuser to function properly it must be horizontal to ensure that water pressure outside each port will be the same. In addition, the alignment of the diffuser should be approximately parallel to the sea floor contours to reduce distance above the bottom and for associated structural requirements.

2.2.3.1 Diffuser Length and Depth

Two potential diffuser depths were considered for the proposed outfall: 21 m (70 ft) and 46 m (150 ft). At each depth, four diffuser lengths, 100 m (328 ft), 200 m (656 ft), 300 m (984 ft), and 400 m (1,310 ft), were considered. The depths were chosen based upon the bathymetry and characteristics of the sea floor in the region of the proposed diffuser. A description of sea floor characteristics is provided in Section 3.4 of this document. The sea floor is somewhat less steep and relatively more stable at 21 m (70 ft) and 46 m (150 ft) than at depths in between or at depths greater than approximately 51 m (167 ft) (see Figure 1.4-1). Below 21 m (70 ft), the bottom is covered with sand. The 46-m (150-ft) depth was considered to be a viable location for diffuser construction due to the milder slopes and apparent relative stability of the sand. Diffuser construction on the steeper slopes at intermediate and greater depths, characterized by loose, coarse sand, would be more costly and would threaten the long-term structural and functional stability of the diffuser. Observations of the steeper slopes suggest that large south swells shift sand on the steep slopes. The City has experienced problems with migrating sand piling against the diffuser of the Sand Island Outfall, which they own and operate.[6] Effluent dilution was modeled for the four diffuser lengths at both depths. The model provided initial dilution,[7] plume rise, and the horizontal distance required to achieve dilution ratios of 500:1 and 1000:1 at the water's surface.[8] Based on the initial results, two options were selected for detailed plume modeling: a 400-m (1,310-ft)-long diffuser at the 21-m (70-ft) depth and a 200-m (656-ft)-long diffuser at the 46-m (150-ft) depth. Modeling results for these two diffuser options are presented in Table 2.2-1 for both summer and winter water density stratification conditions, which vary due to summer heating of the water surface. For each diffuser, the plumes are categorized into surfacing or submerged during both winter and summer. The model indicates that, during summer, the plume

[6]Sea Engineering , Inc. (March 1996) MCON Project P-497: *Oceanographic Study for Outfall Extension for Wastewater Treatment Plant at Fort Kamehameha.*

[7]Initial dilution is the dilution ratio at the top of the rising plume.

[8]Sea Engineering , Inc. (March 1996).

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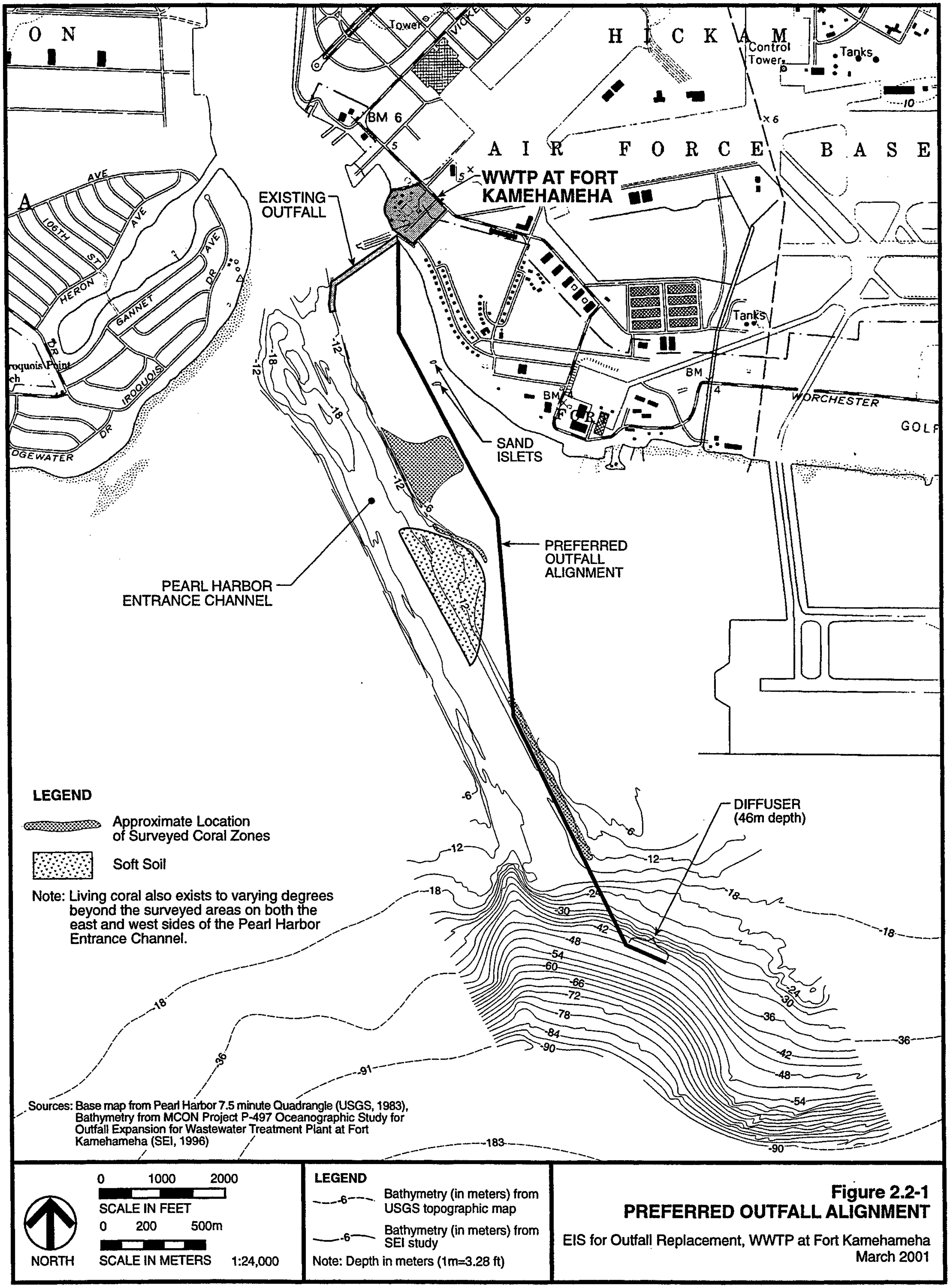

Figure 2.2-1
PREFERRED OUTFALL ALIGNMENT

EIS for Outfall Replacement, WWTP at Fort Kamehameha
March 2001

Table 2.2-1
Effluent Plume Modeling Results for 46-m (150-ft) and 21-m (70-ft) Diffuser Depths*

		Frequency of Occurrence (% of time)		Lowest Initial Dilution		Highest Initial Dilution		Average Initial Dilution		Average Plume Rise Height in m (ft)	
Season	Plume Type	46 m (150 ft)	21 m (70 ft)	46 m (150 ft)	21 m (70 ft)	46 m (150 ft)	21 m (70 ft)	46 m (150 ft)	21 m (70 ft)	46 m (150 ft)	21 m (70 ft)
Winter	Submerged	28.6	0.4	126:1	215:1	1,504:1	757:1	487:1	527:1	34.8 (114)	17.8 (58)
	Surfacing	71.4	99.6	346:1	211:1	1,878:1	1,178:1	564:1	417:1	46 (150)	21 (70)
	Total	100.0	100.0								
Summer	Submerged	53.5	4.8	111:1	124:1	1,602:1	941:1	402:1	428:1	30.0 (98)	15.3 (50)
	Surfacing	46.5	95.2	342:1	208:1	1,922:1	1,243:1	571:1	432:1	46 (150)	21 (70)
	Total	100.0	100.0								

*The 46-m (150-ft)-deep diffuser is 200 m (656 ft) long; the 21-m (70-ft)-deep diffuser is 400 m (1,310 ft) long.

from the 46-m (150-ft)-deep diffuser would surface 46.5 percent of the time with an average initial dilution of 571:1. During winter, it would surface 71.4 percent of the time with an average initial dilution of 564:1. The 21-m (70-ft)-deep diffuser would surface 95.2 percent of the time during summer with an average initial dilution of 432:1, and 99.6 percent of the time during winter with an average initial dilution of 417:1.

Based on the reduced occurrence of a surfacing plume and the greater dilutions available when the plume does surface, the 46-m (150-ft) depth was selected as the preferred diffuser depth. Because only marginal benefits were projected by the initial modeling for the 400-m (1,310-ft) diffuser at this depth, 200 m (656 ft) was selected as the preferred diffuser length. The estimated ZOM for this diffuser, based upon nitrate + nitrite nitrogen as the limiting parameter, is approximately 910 m (2,980 ft) long and 750 m (2,460 ft) wide with an approximate area of 68 ha (168 ac). It is much smaller than the existing ZOM, which covers an area of approximately 267 ha (600 ac) (see Figure 1.2-1), so it will affect less of the marine environment.

2.2.3.2 Outfall Alignment

The preferred outfall alignment follows the same general alignment as the trenchless corridor discussed in the DEIS, with modifications to avoid soft soils and areas of living coral.

Figure 1.4-1 depicts the various alignments considered. The areas that are avoided by the preferred alignment include:

- An area extending approximately 600 m (2,000 ft) along the Pearl Harbor Entrance Channel, where the reef edge forms an "inlet" or "bight" along the channel wall, consisting of very deep, fine, unconsolidated soils that would be unsuitable for support of the outfall pipe.

- Areas of living coral that are concentrated in zones on the reef flat and channel wall and are also located sporadically on the ocean bottom seaward of the channel.

After design analysis, site-specific investigation of both benthic and subsurface conditions, and consideration of construction methods, selection of the preferred alignment was based upon the following criteria:

- Constructability,
- Construction cost,
- Minimum potential impacts upon the benthic community of the reef flat and reef slope offshore of Fort Kamehameha (with emphasis placed upon protection of living coral),
- Minimum potential impacts upon the bird habitat of the sand islets within the shallow reef area,
- Minimum potential disruption to marine navigation, and
- Long-term stability and reliability of the proposed outfall.

The preferred alignment crosses the submerged sand bars to the west of the two sand islets, similar to alignment option 2. It then circumvents an area of established coral growth and the bight area of poor soils to join the original alignment along the eastern edge of the Pearl Harbor Entrance Channel south of the bight. The alignment within the channel was moved to the bottom of the channel slope, where corals are not present, but it remains outside the navigational channel itself. The preferred alignment will be easier and less costly to construct than other possible alignments across the shallow reef flat, because it maximizes the length of outfall across the relatively barren part of the reef flat. The bottom of the Pearl Harbor Entrance Channel along the preferred alignment is of predominantly coarser grained material, which would be more suitable for ocean disposal after trenching. Considerable silt deposits exist in the bottom of the channel along the north end of alignment option 1.[9] The reef flat and slope have areas with concentrations of living coral growth on the shallows and along the upper portions of the channel wall which are largely avoided by the preferred alignment (see Figure 1.4-1).

Although alignment options 1, 2, and 3 would cross the reef flat more directly to the entrance channel, all three are impractical due to the inability of the soft soils in the bight area to support the outfall pipe. Also, alignment option 1 would cross an area of silt deposits at the bottom of the inner portion of the Pearl Harbor Entrance Channel, and alignment option 2 would cross an area of substantial living coral.

A fourth alignment option, similar to alignment option 3 but circumventing the bight area of soft soils, was considered (see Figure 1.4-1, alignment option 4). This alignment was rejected after the detailed investigation, because a strip of well-established coral growth was observed along the northern portion of the shoreward edge of the bight. As a result, the alignment could not be adequately adjusted to avoid a portion of this coral bed.

A potential alignment across the Pearl Harbor Entrance Channel to a diffuser location west of the channel was dismissed early in the planning phase of this project because of the risk of fouling and damage from a ship's anchor and the hazards imposed by channel dredging activities. The possibility of aligning the outfall overland through Hickam Air Force Base (AFB) was also eliminated in the early planning phase due to the high potential for encountering cultural resources and disturbing the existing residential area.

[9]Sea Engineering, Inc. (March 1996).

2.2.4 Construction Methodology

Two methods of outfall construction are considered for this project: open trenching and trenchless technology. Although open trenching is considered a standard construction methodology, more recently developed trenchless technologies are also considered because they potentially offer some advantages over open trenching for all or part of the outfall installation. A brief description of these methods, including advantages and disadvantages, is presented in the following subsections. The preferred construction plan, configured to reduce both environmental impacts and costs, involves a combination of the two technologies.

2.2.4.1 Open Trenching Method

Portions of the alignment will be constructed using open trenching. The shallow reef flat and deeper channel portions of the route will be constructed in this manner, using land-based and barge-based excavation methods, respectively. A typical section for open-trench construction is shown in Figure 2.2-2.

At depths of less than about 1 m (3 ft), large rubber-tired or tracked equipment will be used across the reef flat in a construction corridor. No open-trench construction will occur on the reef flat in water depths averaging greater than about 1 m (3 ft). For excavation of harder material, some form of impact excavation, such as spudding, which involves repeated dropping of a hard, heavy object to break the material for excavation, may be used. In waters deep enough for barge work, excavation will be accomplished by floating equipment.

Construction Across the Reef Flat

Open trenching across the shallow portion of the reef flat will be accomplished with large rubber-tired or tracked excavation and hauling equipment. A haul route adjacent to the trench will be built up with excavated native material topped with matting. An additional access route may be provided for construction of the southern portion of the trench section on the reef flat. This route (see also Section 2.2.4.6 and unpaved road location on Figure 2.2-6) would access the reef between the Fort Kamehameha housing district and the Fort Kamehameha wetlands at a location that has previously been used for vehicular access to the reef. The alignment of this access across the reef has been inspected and is barren of living coral. A construction corridor approximately 30 m (100 ft) wide along the trench alignment and 6 m (20 ft) wide along the southern access route will be established, within which all vehicle operation and excavation will be confined. Silt curtains will be placed around the construction corridor to reduce sediment transport beyond the corridor. The 107-cm (42-inch)-diameter outfall pipe will be placed in bedding gravels within a trench approximately 3 m (10 ft) deep and protected with tremie concrete or articulated concrete mats. The top 0.3 m (1 ft) will be backfilled with native material or coral sand. The surfacing material along the haul routes will be removed and the surface restored to approximately original contours after construction.

Construction in the Pearl Harbor Entrance Channel

Where the outfall alignment follows the edge of the Pearl Harbor Entrance Channel, the pipe will be placed in a trench approximately 2 to 3 m (7 to10 ft) deep (beneath anticipated future dredging limits) and protected by tremie concrete or articulated concrete mats. Construction in this area will be performed from barges.

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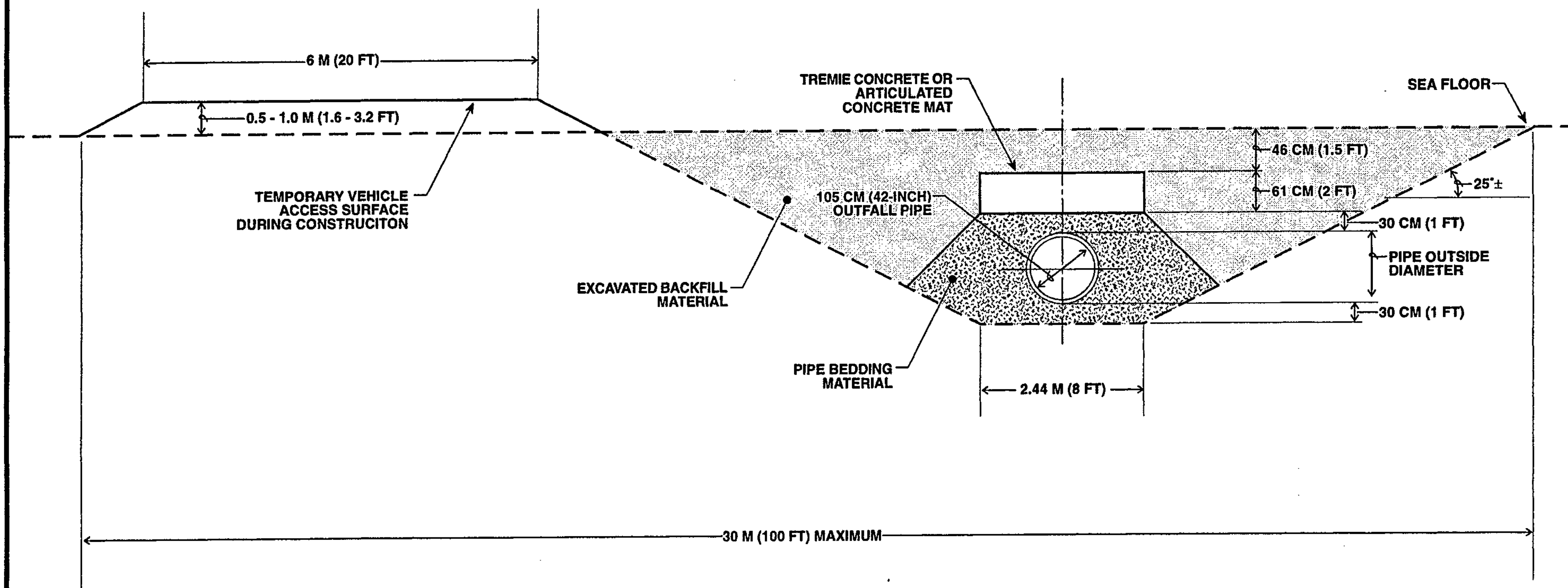


Note: Dimensions and angles are approximate

NOT TO SCALE

Figure 2.2-2
TYPICAL TRENCH SECTION FOR OUTFALL CONSTRUCTION ON REEF FLAT

EIS for Outfall Replacement, WWTP at Fort Kamehameha
March 2001

Construction Through the Rock Area

From the seaward end of the Pearl Harbor Entrance Channel to the 20-m (66-ft) depth, a distance of approximately 700 m (2,270 ft), the sea floor consists of limestone and coral rubble. Spudding, a type of impact excavation, may be necessary for excavation of the hard coral rock. The pipe will be placed in a trench approximately 2 to 3 m (7 to10 ft) deep and protected with tremie concrete or articulated concrete mats. Construction in this area will also be performed from barges.

Advantages and Disadvantages of Open Trenching

Open trenching has the following advantages:

- It costs less than trenchless construction for excavations less than 5 m (16 ft) deep.
- Excavation and removal of material can often be performed by conventional equipment.
- It is less susceptible to subsurface uncertainties and obstructions (spudding can be used for removal of hard rock).

Disadvantages of open trenching include the following:

- Spudding, which is slow and costly, may be required to trench through areas of hard rock (this is included in the cost estimate presented in Section 2.2.6).
- Large areas (approximately 30 m by 1,400 m [100 ft by 4,600 ft], or 4.2 ha [10.4 ac] or approximately 6 percent) of the shallow reef flat will be disturbed by the construction corridor.
- Stability of trench sides may be poor, depending on the subsurface soil conditions.
- Approximately one third of the width of the Pearl Harbor Entrance Channel could be temporarily closed to shipping traffic during construction in the channel; this would only affect the passage of aircraft carriers, as discussed in Section 4.9.
- Open trench construction causes more water column turbidity and resulting sedimentation than trenchless methods.
- Open trench construction produces a larger quantity of excavated material for disposal than trenchless methods.
- Trench access is difficult in waters of intermediate depth (1 to 4 m [3 to 13 ft]).

2.2.4.2 Trenchless Construction Methods

Two trenchless pipe installation techniques, microtunneling and horizontal directional drilling, were evaluated for this project. Microtunneling is a pipe-jacking technique that uses a remote controlled tunnel-boring machine to excavate, while at the same time pipe is installed behind the machine by pipe jacking from a jacking pit. Microtunneling can only be used for a straight pipe alignment and profile. The accuracy of this method is good when properly executed.

Horizontal directional drilling is a technique that uses a guided bit to drill a hole that is subsequently enlarged by back reaming (if needed). When the hole has reached the required size, the pipe is pulled into the hole in a single operation. Directional drilling produces a pipeline profile that is curved but may have straight sections. The alignment, therefore, may be either curved or straight; however, a straight alignment is preferred. Because the accuracy of this method is less than that of the microtunneling method, and because it is important to maintain a negative slope for the entire length of the outfall, horizontal directional drilling was eliminated from consideration for this project.

Because microtunneling is not suitable for direct installation of high-density polyethylene (HDPE) pipe, either a steel casing would need to be installed and the HDPE pipe placed inside the casing, or another pipe material would need to be used for the microtunneled portion of the outfall. For the steel casing method, the annulus between the pipes would need to be grouted. To directly install the outfall pipe by microtunneling, concrete, steel, or fiberglass pipe would need to be used. Microtunneling requires a number of access pits with horizontal dimensions ranging from 4 to 9 m (13 to 30 ft).

Because microtunneling is more susceptible to variations in subsurface conditions, careful geotechnical evaluation and alignment selection are required. Additional geotechnical evaluation, performed since publication of the DEIS, has indicated that microtunneling is a feasible construction method for outfall installation on the reef flat. A conceptual microtunneling jacking pit on the reef flat is shown on Figure 2.2-3.

Advantages and Disadvantages of Trenchless Methods

Advantages of trenchless pipe installation methods include the following:

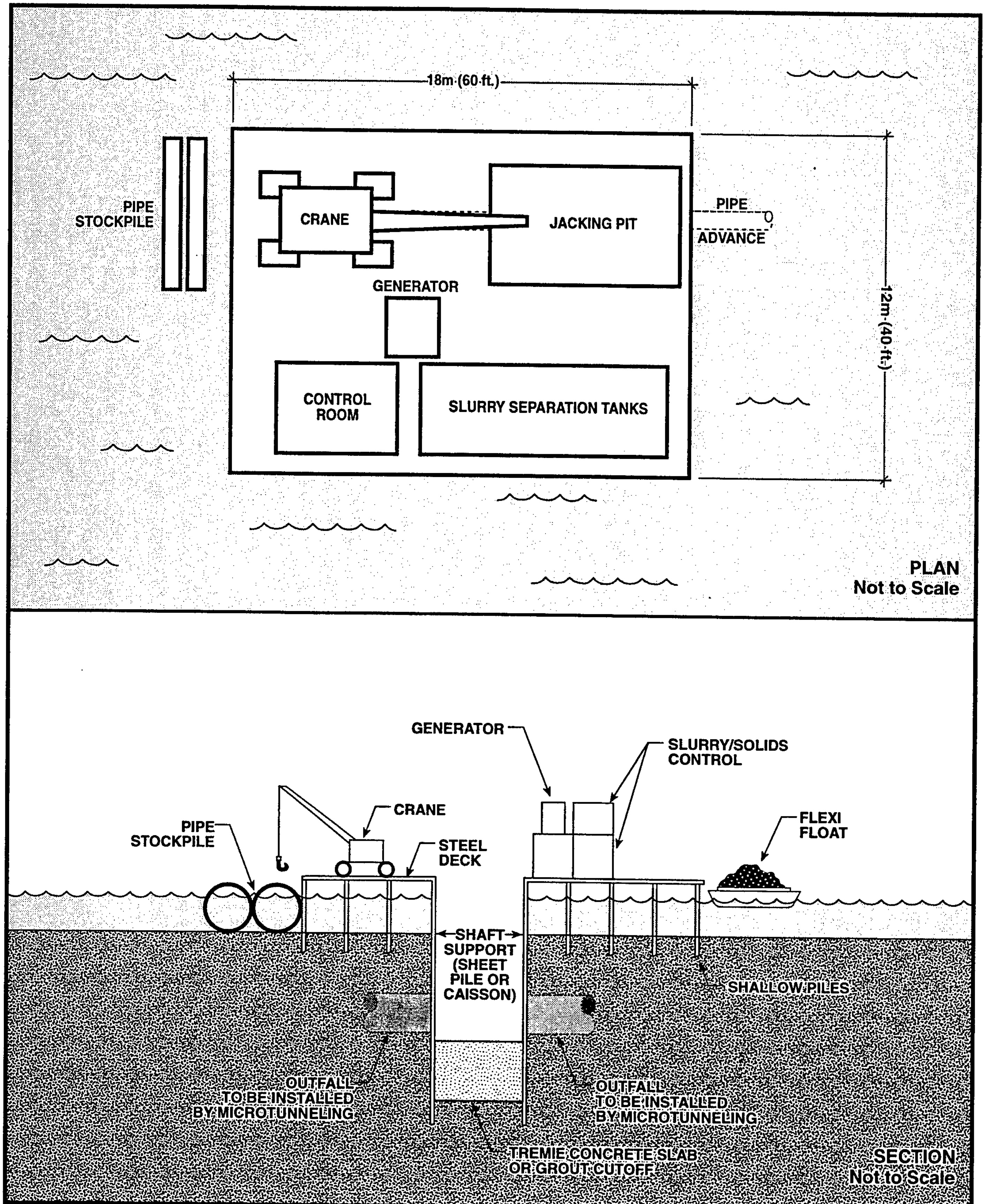
- The impact upon the shallow reef flat is reduced relative to open trenching because the area of open excavation is small.
- Construction in the intermediate depth zone (from 1 to 4 m [3 to 13 ft]), which is too deep for land-based equipment to function efficiently and too shallow for barge-based construction without excavating a barge channel, is facilitated.
- Less sediment is suspended in the water column than by open trenching.
- The excavated volume of material requiring disposal is reduced.

The disadvantages identified for microtunneling a portion of the outfall installation include the following:

- Greater geotechnical investigation, design, and construction planning efforts are required to reduce the risks associated with subsurface uncertainties.
- Obstructions, if encountered, may need to be removed by surface excavation methods, similar to but deeper than open trenching.
- Access to jacking and receiving pits is required. Jacking pits require a larger equipment and materials staging area for construction activities than receiving pits.
- Drilling mud requires separation from excavated material for return and reuse at the drill head.
- Unit-length costs for microtunneling at depths less than 5 m (16 ft) are higher than unit-length costs for open trenching.

2.2.4.3 Pile-Supported Piping in the Sandy Zone

Neither open trench nor trenchless methods of pipe burial would be suitable for construction of the outfall through the steeper sandy section, from the 20-m (66-ft) to the 46-m (150-ft) depths. Construction of the outfall in this section will require the installation of piles to stabilize and support the pipe. The pipe will be secured to underlying pile caps and tie-beams constructed just above the surface of the sea floor. This approach will facilitate installation of the pipe, as well as any future repairs that may be required in the event that the pipe is damaged. The section of the outfall including the diffuser, located in the sandy area deeper than 40 m (130 ft) where slopes are less steep, may also be constructed by this method to secure the diffuser and prevent sand from piling against it and potentially impairing its performance.



Source: Woodward-Clyde Federal Services, Inc. (April 1998) *Feasibility Report Horizontal Directional Drilling and Microtunneling Construction Methods, Ocean Outfall Extension, Wastewater Treatment Plant at Fort Kamehameha.*

Figure 2.2-3
CONCEPTUAL MICROTUNNELING JACKING PIT ON REEF FLAT
EIS for Outfall Replacement, WWTP at Fort Kamehameha
March 2001

2.2.4.4 Connection to Existing Outfall

One of the last items of construction will be the connection of the new outfall to the existing outfall so that treated effluent may flow through the existing outfall in emergency situations. The connection will be made by removing an existing blind flange at the 75-cm (30-inch) check valve in the existing effluent discharge manifold and installing a prefabricated transition section which will connect to the new outfall pipe. Sections of the existing piping immediately upstream and downstream of the connection point will be exposed and the pipe trench prepared. The connection will be made during low tide when the WWTP is experiencing a low flow period. It will probably be necessary to dewater the land portion of the trench.

2.2.4.5 Excavated Material Disposal

Because the proposed outfall alignment avoids areas of recent sedimentation, the excavated material is expected to be free of trace pollutants such as chlorinated hydrocarbons and heavy metals. Material excavated from the shallow reef flat will be reused or disposed as follows:

- Some material will be used for building up the temporary construction access road along the trench.
- Some material will be dewatered for storage and reused as backfill for the trench and/or access pits.
- Excess excavated material may be disposed at an USEPA-designated South Oahu ODMDS, if authorized by the USACE after analysis of the material, under Section 103 of the MPRSA, or it may be dewatered for land disposal.

For open-trench and microtunneling construction, approximately 45,000 cubic meters (m^3) (59,000 cubic yards [yd^3]) of material will be excavated from the reef flat. Assuming approximately 30 m (100 ft) of trench would be open at once, approximately 450 m^3 (589 yd^3) would need to be stockpiled at any one time. Material excavated in the deeper areas using barge-mounted equipment will be side cast or disposed at an approved site, depending upon the regulatory decision of the USACE.

Disposal of approximately 18,264 m^3 (23,890 yd^3) and about 10,543 m^3 (13,790 yd^3) of excavated material from the reef flat and the outer portion of the channel, respectively, at the South Oahu ODMDS has been proposed. The South Oahu ODMDS received final designation as a deep-ocean site for disposal of dredged materials following a Final EIS published by the USEPA in 1980.[10] The South Oahu ODMDS is located about 5.6 km (3.5 mi) south of Pearl Harbor.

The dredged material has been evaluated as part of the DA permit application process. Substrate at the South Oahu ODMDS, as described in past studies,[11] was compared to the material proposed for disposal. It was determined that the proposed dredged material is substantially the same as the substrate at the proposed disposal site. In addition, the site of proposed dredged material was determined to be far removed from known or potential sources of contamination, due to the absence of mechanisms which aid in the migration of pollutants from the nearest sources to the reef flat or outer channel. Thus, there is reasonable assurance that the material has not been

[10] Department of the Army (undated) *Special Joint Public Notice Site Management Plan (SMP) for the Hawaiian Ocean Dredged Material Disposal Sites.*

[11] M.E. Torresan, M.A. Hamption, M.H. Gowen, J.H. Barber, Jr., L.L. Zink, T.E. Chase, F.L. Wong, J.T. Gann, and P. Dartnell (undated) *Final Report: Acoustic Mapping of Dredged Material Disposal Sites and Deposits in Mamala Bay, Honolulu, Hawaii.* USGS Open-File Report 95-17; U.S. Environmental Protection Agency (1980) *Final Environmental Impact Statement (EIS) for Hawaii Dredged Material Disposal Sites Designation.*

contaminated by such pollution.[12] Based on this information, the dredged material appears to be suitable for disposal at the South Oahu ODMDS.

2.2.4.6 Specific Outfall Construction Methods

As discussed in Section 2.2.4, the proposed outfall will be constructed using both open trenching and trenchless construction methods. The portions of the outfall alignment where each construction method will be used are shown in Figure 2.2-4. The total construction duration is expected to be approximately two years, assuming concurrent construction activities along the outfall. Construction activities along the length of the outfall are summarized below:

- Land-based trenching will occur on the shallow reef flat using large rubber-tired or tracked excavation and hauling equipment. A haul route adjacent to the trench will be composed of excavated native material topped with matting. A construction corridor approximately 30 m (100 ft) wide will be established along the trench alignment and surrounded by silt curtains to reduce sediment transport. An additional access route may be provided for construction of the southern portion of the trench section on the reef flat (see Figure 2.2-6). Excavated materials will be used for building up the construction access route along the trench, dewatered for storage ashore, and reused as backfill for the trench. Excess material will be disposed at an USEPA-approved ocean disposal site, if authorized by permit, or dewatered for land disposal. Construction of this section will last approximately nine months.

- Microtunneling will be used to construct the seaward portion of the outfall on the shallow reef flat. A jacking pit and two receiving pits will be required for the microtunneling activities. A construction barge accessway from the Pearl Harbor Entrance Channel to the jacking pit will be required for movement of equipment and excavated material. Excavated materials will be separated from the drilling mud slurry, dewatered for storage, and reused as backfill for the access pits. Excess material will be disposed at the South Oahu ODMDS, if authorized by permit, or dewatered for land disposal. Construction of the microtunneled section is anticipated to last approximately five months.

- Open trenching methods will be used for construction of the outfall along the edge of the Pearl Harbor Entrance Channel and for the section of the outfall from the seaward end of the Pearl Harbor Entrance Channel to the 20-m (66-ft) depth. Construction activities in this area will be performed from barges. Sea-floor disturbance will be confined to an established 30-m (100-ft)-wide construction corridor. Excavated materials will be side cast for backfill or disposed at the South Oahu ODMDS. Construction of this section will take approximately 13 months.

- Construction of the outfall through the steeper sandy section and the diffuser on the sloping, sandy bench, from the 20-m (66-ft) to the 46-m (150-ft) depths, requires the installation of piles to stabilize and support the pipe. The pipe will be secured to underlying pile caps and tie-beams constructed just above the surface of the sea floor. Sea-floor disturbance will be confined to an established 30-m (100-ft)-wide construction corridor. Outfall construction in the sandy area will take approximately three months.

- The construction contractor will be required to perform an independent visual survey for ordnance items prior to commencement of work within the construction corridor using a diving unexploded ordnance specialist. In addition, the contractor will be required to scan the

[12]Department of the Navy (December 1998) *Evaluation of Proposed Dredged Material Outfall Replacement for Wastewater Treatment Plant at Fort Kamehameha, Navy Public Works Center, Pearl Harbor, Hawaii.*

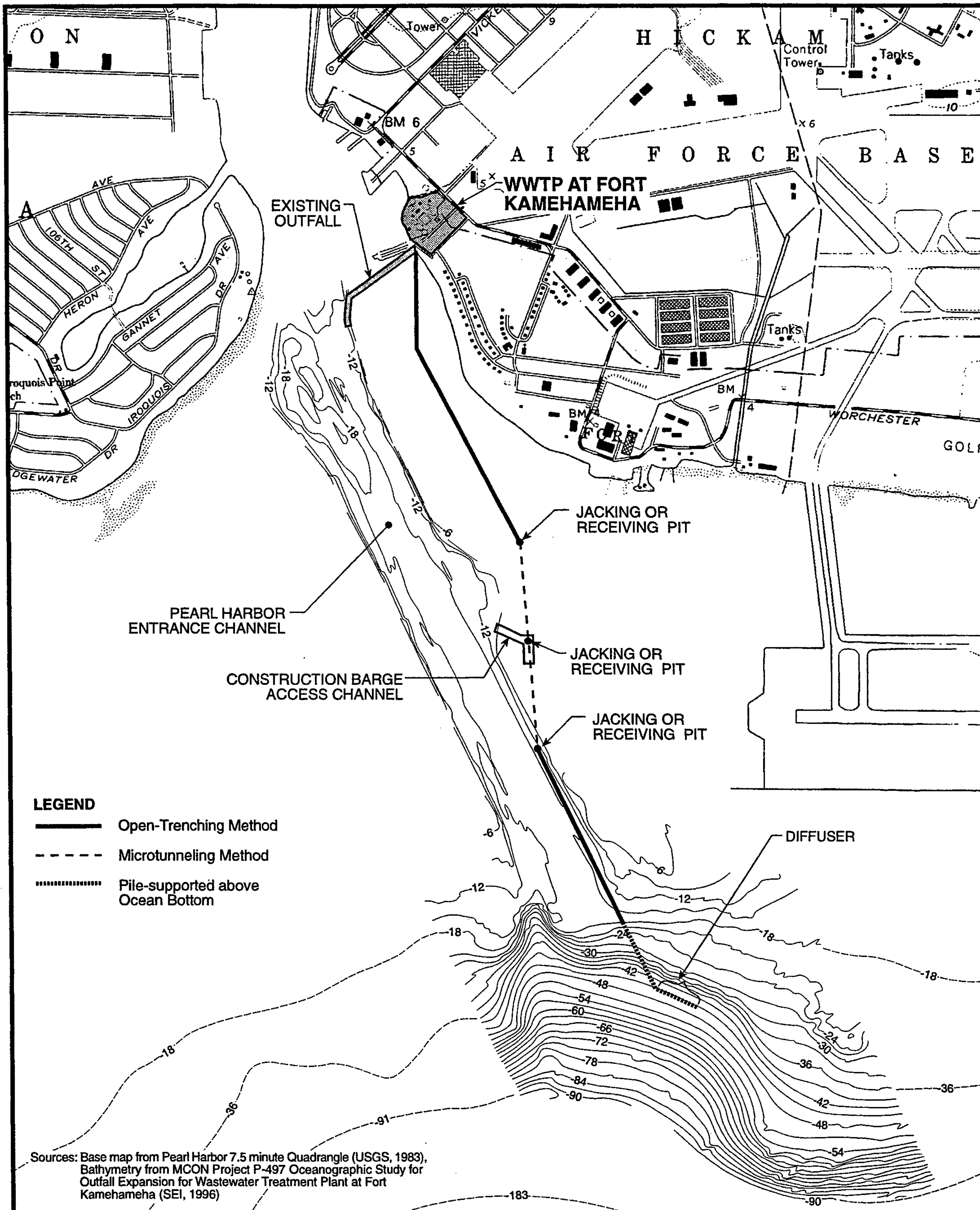


Figure 2.2-4
OUTFALL CONSTRUCTION METHODS

EIS for Outfall Replacement, WWTP at Fort Kamehameha
March 2001

pile driving location prior to start of pile driving. In the unlikely event that one or more ordnance items are detected within the established construction corridor, the contractor will cease construction activities and notify the construction management engineer or his representative, who will in turn notify the appropriate Navy personnel in accordance with Commander in Chief Pacific Fleet Instruction 8027.1N. Navy EOD personnel will perform a site investigation. If it is determined that the ordnance items cannot be safely picked up and carried away, an engineering solution will be implemented to avoid in-place detonation of ordnance. A portion of the outfall will be realigned around the ordnance. The realigned portion of the outfall will be located within the construction corridor and all construction activities will be confined to the corridor. Realignment techniques include, but are not limited to, utilizing the bending radius properties of the HDPE pipe to provide the necessary clearance from the ordnance. The realignment technique and specific construction methods to be used will be proposed by the contractor for Navy approval.

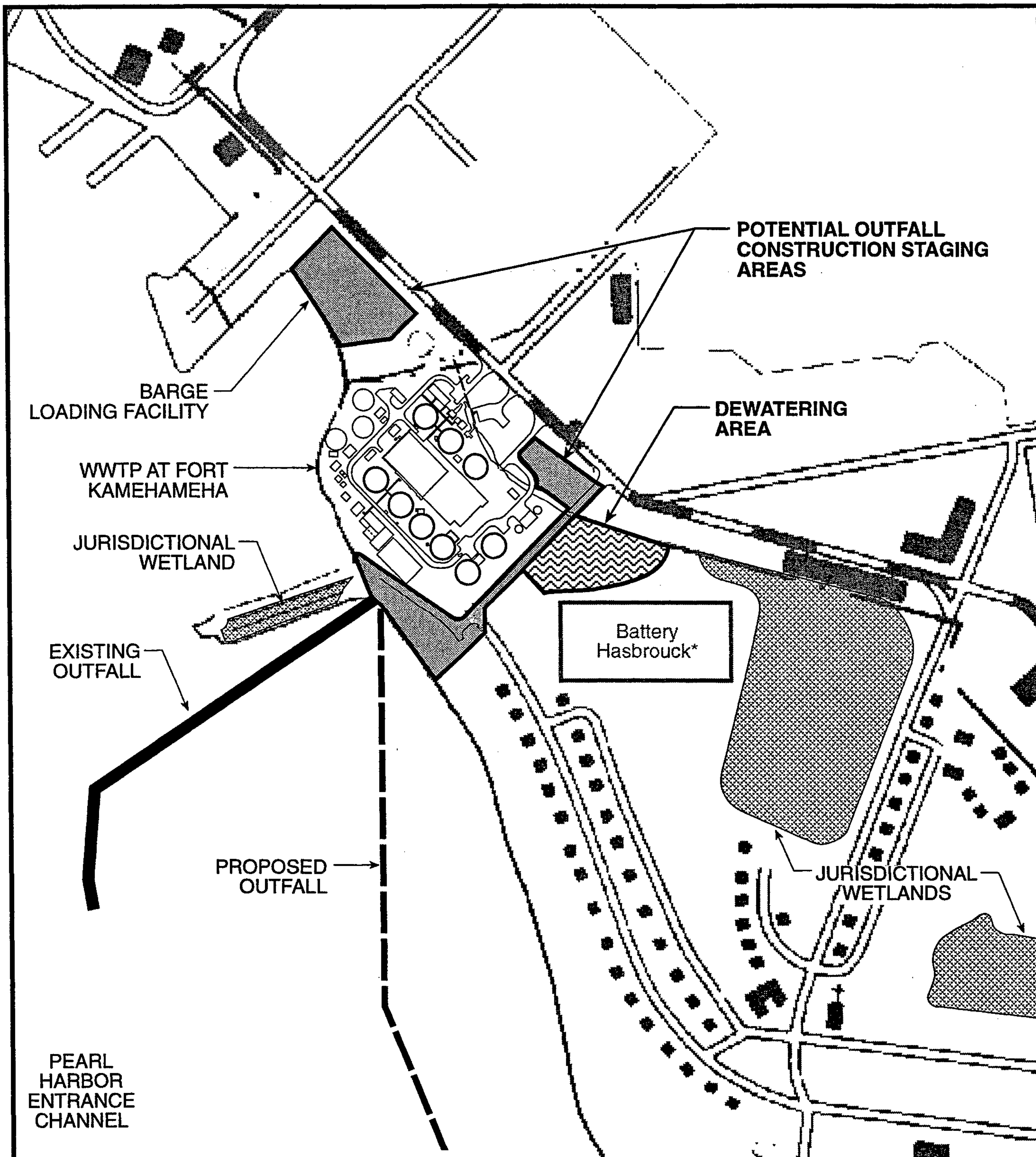
2.2.4.7 Construction Staging

Construction staging and dewatering areas are needed to provide the contractor with sufficient space to store construction materials and equipment, perform equipment maintenance operations, construction office and workers' parking. The proposed construction staging and dewatering areas are located near the WWTP as shown on Figure 2.2-5. It is estimated that a total of approximately 3 ha (7.5 ac) will be required for staging and dewatering, which will accommodate both open trenching and microtunneling requirements. Staging areas may require fencing for security and safety reasons.

A dewatering area will be used to dry excavated material before temporary storage or for land-based disposal, if required. As indicated in Section 2.2.4.5, dewatering may be needed for the land-based portion of the work. Disposal of dewatering effluent will be by percolation and evaporation. Should these methods be insufficient, they will be augmented with subsurface injection or surface discharge. Should underground injection or discharge to surface waters be required for disposal of dewatering effluent, permits for such disposal actions will be obtained by the contractor prior to discharge.

The construction staging area will provide a location for parking and maintaining construction equipment and for storage of repair parts, fuels, lubricants, and fluids. It also will provide space for receiving, storing, preparing, and dispatching construction materials, and for related administration. Water craft supporting the construction effort will use the water area adjacent to the staging area north of the WWTP for temporary mooring and to load construction materials. This staging area is also the site for a barge loading facility for excavated material. If the contractor uses the staging area for storage of fuels, lubricants, or automotive fluids, a spill prevention, control and countermeasures plan will be required for that storage. Whether the contractor uses on-site petroleum oil lubricant storage or a vehicle servicing truck from off-site, all vehicle servicing will be performed in the staging area, not on the reef flat or adjacent shoreline areas. Project specifications will require the contractor to have an emergency response plan for releases to the water, and to stage the necessary equipment and materials to implement the response.

To accommodate hauling of excess excavated material across the reef flat (for disposal), a reef access route on an unpaved road south of the Fort Kamehameha housing (as shown on Figure 2.2-6) may be used. This would reduce hauling distances and construction traffic on the reef flat fronting the Fort Kamehameha housing area during construction of the southern open-trench section on the reef flat. This alignment has been inspected and is barren of coral. The shoreline access point is through a small park with an unpaved road. The unpaved road extends from the



Source: USGS Pearl Harbor Hawaii Quadrangle 7.5 minute Topographic Series, 1983

Air Force Center for Environmental Excellence (June 1997) *Final Integrated Natural Resources Manangment Plan for Hickam AFB, Oahu; Bellows AFS, Oahu; Hickam POL Pipeline, Oahu; Kaala AFS, Oahu; Kaena Point STS, Oahu; Kokee AFS, Kauai; and Palehua Solar Observatory, Oahu (15th Air Base Wing Installations).*

NORTH

0 100 300 500
SCALE IN FEET

0 40 80 120 160 200m
SCALE IN METERS 1:6,000

*Battery Hasbrouck is part of the historic Battery District as discussed in Section 3.6.2.

Figure 2.2-5
POTENTIAL OUTFALL CONSTRUCTION STAGING & DEWATERING AREAS
EIS for Outfall Replacement, WWTP at Fort Kamehameha
March 2001

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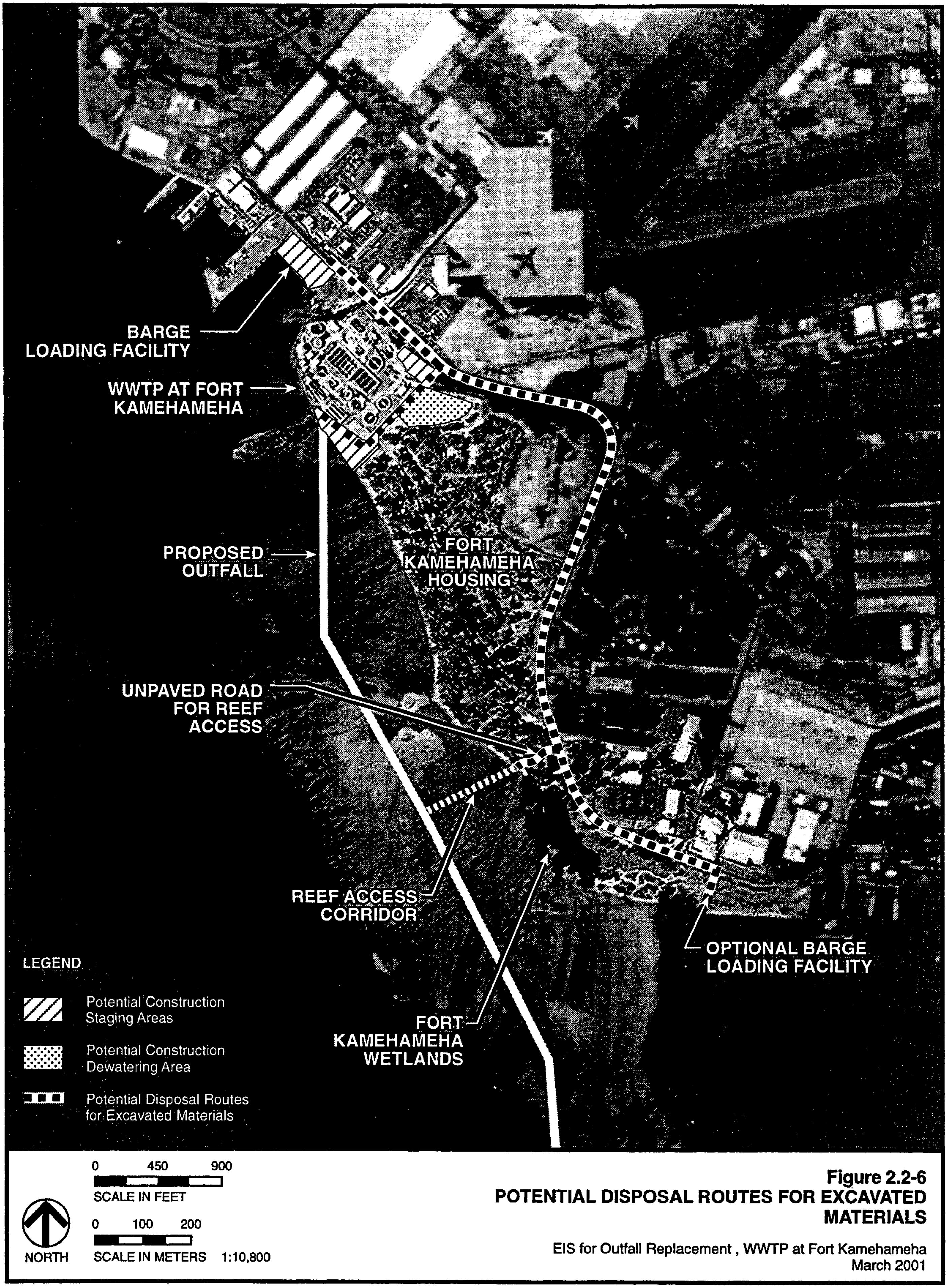

Figure 2.2-6
POTENTIAL DISPOSAL ROUTES FOR EXCAVATED MATERIALS

EIS for Outfall Replacement , WWTP at Fort Kamehameha
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existing hard surface road (to Hickam Harbor) to the shore. The unpaved access road is approximately 90 m (295 ft) long by 15 m (50 ft) wide and crosses over a 60-cm (24-inch) diameter drainage pipe. Excavated material requiring dewatering for land disposal or for storage could be hauled to the construction staging areas either along the outfall alignment or by the reef access route. Existing paved roads would be used to move materials to the appropriate staging and dewatering area or to the barge loading area.

For ocean disposal, a temporary barge loading facility for transfer of excavated material may be constructed at the staging area north of the WWTP or at an optional site located along the western shoreline of Hickam Harbor in an area not frequently used for recreational activities (see Figure 2.2-6). Material bound for the ocean disposal site from the surface trench on the reef flat would be hauled directly to the barge loading facility and deposited into a barge approximately 48 m (150 ft) long which will be towed by a tug boat. The barge will make one trip a day to the South Oahu ODMDS to dispose of the excavated material. Temporary storage of excavated material at either of the barge loading sites would not be allowed. The staging area north of the WWTP has a rock rubble bulkhead and very little living coral. At the optional Hickam Harbor site, a ledge of coral rock extends seaward of the wall approximately 1.8 to 3 m (6 to 10 ft), over which the loading ramp would be constructed in order to load materials into the barge. There is no living coral at this site. At either location, a loading ramp consisting of metal plates built on a temporary foundation over the existing seawall and on temporary pilings over the seaward side of the wall would be required. Also, at either location, temporary piles and buoys would be placed for breasting and mooring the barge. At the end of each day's hauling activities, the contractor will clean the haul route. The entire barge facility will be removed upon completion of the project and the area, including access roads, restored to original condition.

The construction staging and dewatering areas, the areas under consideration for barge loading facilities, and the paved and unpaved roads in the area are under control of the U.S. Air Force. Permission will be obtained from the Air Force through a real estate license or easement for the temporary use of these parcels. This license will provide for utility hook-up on a reimbursable basis. The contract specifications will include requirements for the contractor to water all excavated material, stockpiles, and dirt roads as required for dust control, to prevent unintentional deposition of excavated materials on roadways, and to provide for spill control and emergency response. These specifications will stipulate that all work support areas must be restored to their pre-existing condition following use.

2.2.5 Routine Operations and Maintenance

Routine outfall operation will consist of ensuring that the effluent pumps are activated as required by flow and tidal conditions. Related operations include monitoring the receiving waters in accordance with the permit requirements.

Routine outfall maintenance will consist of maintaining the effluent pump station and control system. The outfall pipe will have no routine maintenance requirements.

2.2.6 Construction, Operations, and Maintenance Costs

The following sections summarize cost estimates for construction and O&M of the outfall and provide a 30-year life-cycle cost for comparison with the other alternatives.

2.2.6.1 Construction

Construction costs for the proposed outfall are provided in Table 2.2-2.

Table 2.2-2
Construction Costs for Proposed Outfall

Construction Method	Unit Cost	Unit	Quantity	Incremental Cost
Mobilization / Demobilization	$1,570,000	lump sum	1	$1,570,000
Land-based Trenching (shallow reef flat)	2,434 (742)	meters (feet)	1,600 (5,250)	3,894,000
Microtunneling (shallow reef flat)	7,720 (2,354)	meters (feet)	650 (2,133)	5,018,000
Barge-based Trenching in Ship Channel	3,931 (1,198)	meters (feet)	1,100 (3,608)	4,324,000
Deep Water Trenching and Pile-Supported Pipe (including diffuser)	9,306 (2,837)	meters (feet)	550 (1,804)	5,118,000
Pile Test Program	352,000	lump sum	1	352,000
Total Construction Cost				$20,276,000

2.2.6.2 Operations and Maintenance

O&M costs for the proposed outfall will include those for the effluent pump station, receiving water quality monitoring, biennial inspections of the outfall, and diffuser repair, as needed. Because repair needs are difficult to project, these costs are based upon complete replacement of the diffuser piping mid-way through the life cycle of the outfall (year 15). These costs are summarized in Table 2.2-3.

2.2.6.3 Life-Cycle Cost

The life-cycle cost, based upon a 30-year life cycle, is calculated in current dollars without inflation. The life-cycle cost for the proposed outfall consists of the capital cost of construction plus the present value of the annual O&M costs. The life-cycle cost is presented in Table 2.2-4.

2.2.7 Feasibility of Outfall Replacement

This alternative is cost competitive and feasible to procure, construct, and operate with existing and anticipated future regulations. There are no significant environmental impacts that cannot be mitigated. This alternative is carried forward for a more detailed comparison of impacts in Chapter 4.

Table 2.2-3
Annual Operation and Maintenance Costs for the Proposed Outfall

Activity	Quantity Unit	Rate*	Incremental Cost
Effluent Pump Station Electricity	12 months/year	$2,600/month	$31,200
Effluent Pump Station O&M	20 worker-days/year	270 ($/worker-day)	5,400
Receiving Water Quality Sampling	20 worker-days/year	270 ($/worker-day)	5,400
Receiving Water Quality Analysis	12 worker-months/year	2,325 ($/worker-month)	27,900
Outfall Inspection	Once every 2nd year	$10,000 lump sum	5,000
Outfall Repair (replace diffuser)	Once at year 15	$677,000 lump sum (=$20,500/year over 30 years)	20,500
Total Annual O&M Cost			$95,400

*The daily rate is based on a contract rate that includes benefits and overhead.

Table 2.2-4
Cost Summary for the Proposed Action

System Component	Capital/ Construction Cost	Annual O&M Cost	Present Value of O&M Cost for 30 Years	30-Year Life-cycle Cost
Proposed Outfall	$20,300,000	$95,400	$1,313,000	$21,613,000

2.3 Underground Injection

Effluent from the WWTP at Fort Kamehameha could be disposed using underground injection wells. Underground injection is practiced in some regions of the mainland U.S. In Hawaii, it is typically used as a backup effluent disposal method, except for smaller facilities (approximately 3,785 m^3/day [1 mgd] and less), such as the City's Kahuku WWTP and Waimanalo WWTP. Underground injection has not been used as the primary effluent disposal method in Hawaii for a facility the size of the WWTP at Fort Kamehameha (49,000 m^3/day [13 mgd]).

Aquifers in the vicinity of the WWTP at Fort Kamehameha are brackish and are not used as potable water sources. The estimated 30-year life-cycle cost of an underground injection system is $34.9 million. Although the life-cycle cost of underground injection is of the same order of magnitude as the cost of the proposed action, the method may not be as reliable as ocean disposal because injection wells are often prone to clogging from suspended and dissolved solids and from bacterial growth. In addition, this alternative has the potential to disturb archaeological and/or human burial sites likely to exist in the vicinity of the project.

2.3.1 Receiving Environment

Treated wastewater from the WWTP at Fort Kamehameha would be injected into the caprock which underlies the area (see Section 3.3.3). The caprock provides a confining cap for deeper volcanic units.[13] Caprock water is generally brackish.[14]

The permeability of the calcareous layers of the caprock is extremely variable. In karstic reef limestone, the permeability can be 6,000 meters per day (m/day) (20,000 feet per day [ft/day]) and higher. In contrast, in areas of lagoonal deposition, the permeability of calcareous material can be as low as several meters per day. The intervening mud layers have permeabilities of a small fraction of a meter per day. They generally function as aquicludes, hydraulically separating the coral layers above and below the mud. Typical permeabilities of the underlying volcanic rocks are likely to be in the range of 300 to 1,500 m/day (1,000 to 5,000 ft/day) (Appendix III).

On the Ewa Plain to the west of the Pearl Harbor Entrance Channel, the uppermost limestone layer of the caprock contains brackish groundwater in a basal lens. It is a significant source of irrigation supply for golf courses and landscaping.

A second underlying limestone layer is used for wastewater disposal by several cogeneration power plants. Injection rates vary from 2,700 to more than 16,000 m^3/day (0.7 to more than 4.2 mgd). Because caprock on the east side of the Pearl Harbor Entrance Channel has not been used for extensive irrigation or for wastewater disposal, very little is known about its hydraulic properties.[15] It is assumed, however, that a similar layer would exist under the WWTP at Fort Kamehameha.

Although the caprock under Fort Kamehameha confines the deeper Waimalu basal aquifer, a major source of drinking water on Oahu, injection into the caprock aquifer should not impact potable supply wells. Groundwater generally flows from basal aquifers to caprock aquifers.[16]

2.3.2 Regulatory Constraints and Requirements

2.3.2.1 Injection Well Siting, Construction, and Operation

Clean Water Act

<u>Section 404 CWA Discharge of Dredged or Fill Material into Navigable Waters of the U.S.</u>

Section 404 of the CWA authorizes the Secretary of the Army to issue permits for the discharge of dredged or fill material into jurisdictional wetlands. A permit for such work must be obtained through the USACE in the form of a DA permit. If the construction of the underground injection wells results in the discharge of excavated material into a jurisdictional wetlands, it will be subject to the provisions and permit requirements set forth in Section 404. A DA permit will be obtained, if required.

[13]Gordon A. Macdonald, Agatin T. Abbott, and Frank L. Peterson (1986) *Volcanoes in the Sea: The Geology of Hawaii.*

[14]F.M. Visher and J.F. Mink (1964) *Groundwater Resources in Southern Oahu.* U.S. Geological Survey Water Supply Paper 1778.

[15]George A. L. Yuen & Assoc., Inc. (May 1988) *Review and Re-evaluation of Groundwater Conditions in the Pearl Harbor Groundwater Control Area, Oahu, Hawaii.* Prepared for the State of Hawaii, Commission on Water Resource Management. Hawaii Department of Land and Natural Resources Report R-78.

[16]George A.L. Yuen & Assoc., Inc. (March 1989) *Groundwater Resources and Sustainable Yield, Ewa Caprock Aquifer.* Prepared for the State of Hawaii, Commission on Water Resource Management. Hawaii Department of Land and Natural Resources Report R-79.

Underground Injection Control

Underground injection of treated effluent from the WWTP at Fort Kamehameha would be regulated under HAR Title 11, Chapter 23, "Underground Injection Control" (UIC). Under HAR 11-23, wastewater injection wells for the WWTP at Fort Kamehameha would inject into an "exempted" aquifer, which the DOH has excluded as an underground source of drinking water. The DOH's UIC line defines exempted aquifers. Specific requirements for injection wells at the WWTP at Fort Kamehameha are as follows:

- <u>Siting</u>. Wells must be located at least 400 m (0.25 mi) from any potable water source located inland of the UIC line and 800 m (0.5 mi) from any potable water source seaward of the UIC line. The nearest potable supply wells drawing from the Pearl Harbor aquifer system are located over 3 km (1.9 mi) from the WWTP at Fort Kamehameha.[17]

- <u>Design and Construction</u>. Underground injection wells must be designed in accordance with their intended use and the BWS's "Water System Standards" (1985). A UIC permit must be obtained from the DOH for construction of each injection well.[18]

- <u>Operation</u>. An operating permit must be obtained from the DOH for the wells, and detailed operational records must be kept.

Although not an applicable regulation on federal lands, HAR 11-62, "Wastewater Systems," provides design criteria for wastewater effluent injection well system capacities. HAR 11-62 indicates that subsurface disposal systems should have a primary disposal component and at least a 100 percent backup disposal component. Both the primary and back up components should have a capacity equal to the peak WWTP wet weather discharge, as determined by the Babbitt maximum factor.[19] This factor is approximately 1.8 for an average flow of 49,000 m^3/day, so the resulting peak flow is approximately 88,000 m^3/day. An underground injection well system for the WWTP at Fort Kamehameha would need a total capacity of approximately 176,000 m^3/day.

2.3.2.2 Navigation

Federal Aviation Administration

Injection wells may be drilled in the flight line of Honolulu International Airport's Reef Runway. Maximum height of any structure in the area proposed for injection wells is 30 m (98 ft) to prevent flight line obstruction. Drilling rigs will be shorter than 30 m (98 ft), and the top of the drilling rigs will need to be flagged and lighted. Additionally, a Notice of Proposed Construction (permit number 7460-1) would be required from the FAA's Western Pacific Region. The FAA would then distribute a NOTAM warning to aircraft using the airport.

[17]State of Hawaii, Department of Health (no date) *Underground Injection Control Maps, Pearl Harbor and Waipahu, Hawaii.*

[18]State of Hawaii, Department of Health (September 1992) *Hawaii Administrative Rules, Title 11, Chapter 23, Underground Injection Control.*

[19]State of Hawaii, Department of Health (August 1991) *Hawaii Administrative Rules, Title 11, Chapter 62, Wastewater Systems.*

2.3.2.3 Protected Species and Habitats

Endangered Species Act

Injection well construction activities, which would be in developed areas, are not anticipated to jeopardize the continued existence of any endangered or threatened species. The ESA of 1973 requires that the USFWS, the NMFS, or both agencies, be consulted when proposed federal actions may affect threatened or endangered species or result in the destruction or adverse modification of critical habitat designated for such species.

Magnuson-Stevens Act/Sustainable Fisheries Act

Injection well construction activities are not expected to impact any designated EFH or HAPC. The Magnuson-Stevens Act requires that the NMFS be consulted when a proposed federal action may adversely affect EFH or HAPC.

Protection of Migratory Birds

Executive Order 13186, *Responsibilities of Federal Agencies to Protect Migratory Birds*, dated January 10, 2001, requires federal agencies taking actions that have, or are likely to have, a measurable negative effect on migratory bird populations to develop and implement a Memorandum of Understanding with the USFWS that promotes the conservation of migratory bird populations. Construction activities for the underground injection alternative could potentially impact migratory bird habitat, depending on the site location.

Protection of Wetlands

Executive Order 11990, dated May 24, 1977, directs federal agencies to avoid long-term and short-term adverse impacts associated with the destruction or modification of wetlands and to avoid direct or indirect support of new construction in wetlands. Construction activities associated with the underground injection alternative have the potential to impact wetland areas, depending on the site location.

2.3.2.4 Cultural Resources

National Historic Preservation Act

The NHPA of 1966 requires federal agencies to consider the effects of their actions on historic sites. The SHPO in the DLNR would need to be consulted to determine means to avoid, reduce or mitigate adverse effects on historic sites. Construction activities associated with the underground injection alternative have the potential to impact historic sites, depending on the site location.

Native American Graves Protection and Repatriation Act

Signed into law in 1990, NAGPRA is intended to protect Native American (including Native Hawaiian) graves. It provides for the inventory and repatriation of Native American human remains and associated funerary objects and addresses the conditions and circumstances when Intentional Excavation and Removal of Native American Human Remains and Objects is permitted. Regulations providing procedures are found at 43 CFR 10.3. If Hawaiian burials are

encountered, NAGPRA requires consultations with appropriate Native Hawaiian organizations. There is a possibility of encountering human burials and other cultural deposits during construction activities associated with the underground injection alternative.

2.3.2.5 Coastal Zone Management

The Hawaii CZM program, which has been approved by the U.S. Department of Commerce, is administered by DBEDT. Although the state's CZM program does not apply to lands and waters under federal ownership or exclusive control, consistency with the state's CZM program would be required due to potential spillover effects of underground injection to nonfederal areas. A consistency determination would be required for the underground injection alternative.

2.3.2.6 Socioeconomics

Environmental Justice for Minority and Low-Income Populations

Executive Order 12898, issued February 11, 1994, requires federal agencies to identify and address, as appropriate, the potential for disproportionately high and adverse environmental effects of its actions on minority and low-income populations. Therefore, the impacts on minority and low-income populations would be identified and mitigated, if necessary. The underground injection alternative would not disproportionately affect minority or low-income populations.

2.3.2.7 Other Regulatory Requirements

Floodplain Management

Executive Order 11988, *Floodplain Management*, issued May 24, 1977, provides floodplain management direction for federal agencies for avoiding to the extent possible the long-term and short-term adverse impacts of occupying and modifying floodplains, and for avoiding direct and indirect support of floodplain development whenever this is practical. Although injection well sites may be located in floodplain areas, the alternative would be designed to minimize floodplain impacts. Impacts would also be mitigated through the use of BMPs and/or standard operating procedures (SOPs).

2.3.3 Physical Description of Underground Injection System

For this alternative, filtered and chlorinated effluent from the WWTP at Fort Kamehameha would be pumped to an injection well field on vacant Hickam AFB land east of the WWTP. This alternative is based upon the assumption that an agreement between the Navy and the Air Force could be negotiated to allow injection wells at the proposed site. If this site cannot be used, a more distant site would be needed, increasing both construction and operational costs of this alternative. In addition to injection wells, the underground injection system would require a new chlorination system, flow equalization basin, booster pumping station, and transmission pipeline. Specific components of the system are as follows:

- <u>Chlorination and Filtration</u>. To inhibit clogging due to solids and biological growth, the effluent must be continually filtered and chlorinated. The effluent filtration and ultraviolet (UV) disinfection systems recently constructed at the WWTP, plus a new chlorination facility, should be used to treat the effluent prior to underground injection. The traveling bridge filters installed as a part of the current WWTP upgrade could be used to filter the effluent prior to

underground injection. Chlorine should be added to the effluent to prevent biological regrowth prior to discharge to injection wells. Because the existing WWTP chlorination facility has been decommissioned, a new chlorination facility would be required.

- Equalization Basin. A new flow equalization basin would mitigate the possibility of off-specification effluent entering the wells.

- Transmission System. An approximately 500-m (1,640-ft)-long, 90-cm (36-inch)-diameter pipeline would be required to convey effluent from the WWTP to a well field to the east of the WWTP. A new low-pressure booster pumping station would be required to push water through the pipeline. The transmission pipeline would connect to a manifold, which would serve individual injection wells in the well field.

- Injection Wells. With an assumed capacity of 16,000 m^3/day (4.2 mgd) each, twelve 50-cm (20-inch)-diameter wells would be required to provide 100 percent backup for the WWTP. This represents two injection well subsystems of six wells each, providing a capacity of 96,000 m^3/day (25.3 mgd) each. This capacity satisfies the design criteria identified in Section 2.3.2.1. If the shallow limestone layer under the WWTP extends to a depth of at least 80 m (260 ft), the injection wells should be solid cased for the first 30 m (100 ft) and left open for the remaining 50 m (160 ft). Individual wells would need to be spaced at least 30 m (100 ft) apart (see Appendix III). Figure 2.3-1 shows the potential location of the injection well field. Much of this area has been identified as a jurisdictional wetland.[20] Installation and operation of the injection well field could occur within the designated wetland without filling or destroying the wetland environment. All required permits would be obtained prior to well field construction.

- Backflush System. To help remediate future well degradation, a backflush system could be installed. Backflush water would enter a collection assembly over the well, which would in turn feed a dedicated line for returning backflush water to the WWTP headworks.

2.3.4 Construction Methodology

Wells would be drilled using either rotary or cable tool technology. Drilling rigs would not exceed the 30-m (100-ft) height limit set by airfield operations. The new transmission and backflush lines could be constructed using either trenching or microtunneling. The new booster pumping station would require site preparation, construction of booster pump pads, possible erection of a control building, and installation of the booster pumps.

Construction of each well is projected to require approximately 30 days. The booster pump station and piping could be built at the same time as the injection wells. Individual injection wells could be drilled simultaneously.

2.3.5 Operations and Maintenance

Routine O&M for injection wells would include pumping water to the wells and backflushing to remove accumulated sediments and bacterial growth. However, over time, well capacity is expected to deteriorate, especially if water containing particulate matter, nutrients, or other contaminants is discharged to the well. These materials can cause clogging of soil pores in the

[20]Air Force Center for Environmental Excellence (June 1997) *Final Integrated Natural Resources Management Plan for Hickam AFB, Oahu; Bellows AFS, Oahu; Hickam POL, Oahu; Kaala AFS, Oahu; Kaena Point STS, Oahu; Kokee AFS, Kauai; and Palehua Solar Observatory, Oahu (15th Air Base Wing Installations).*

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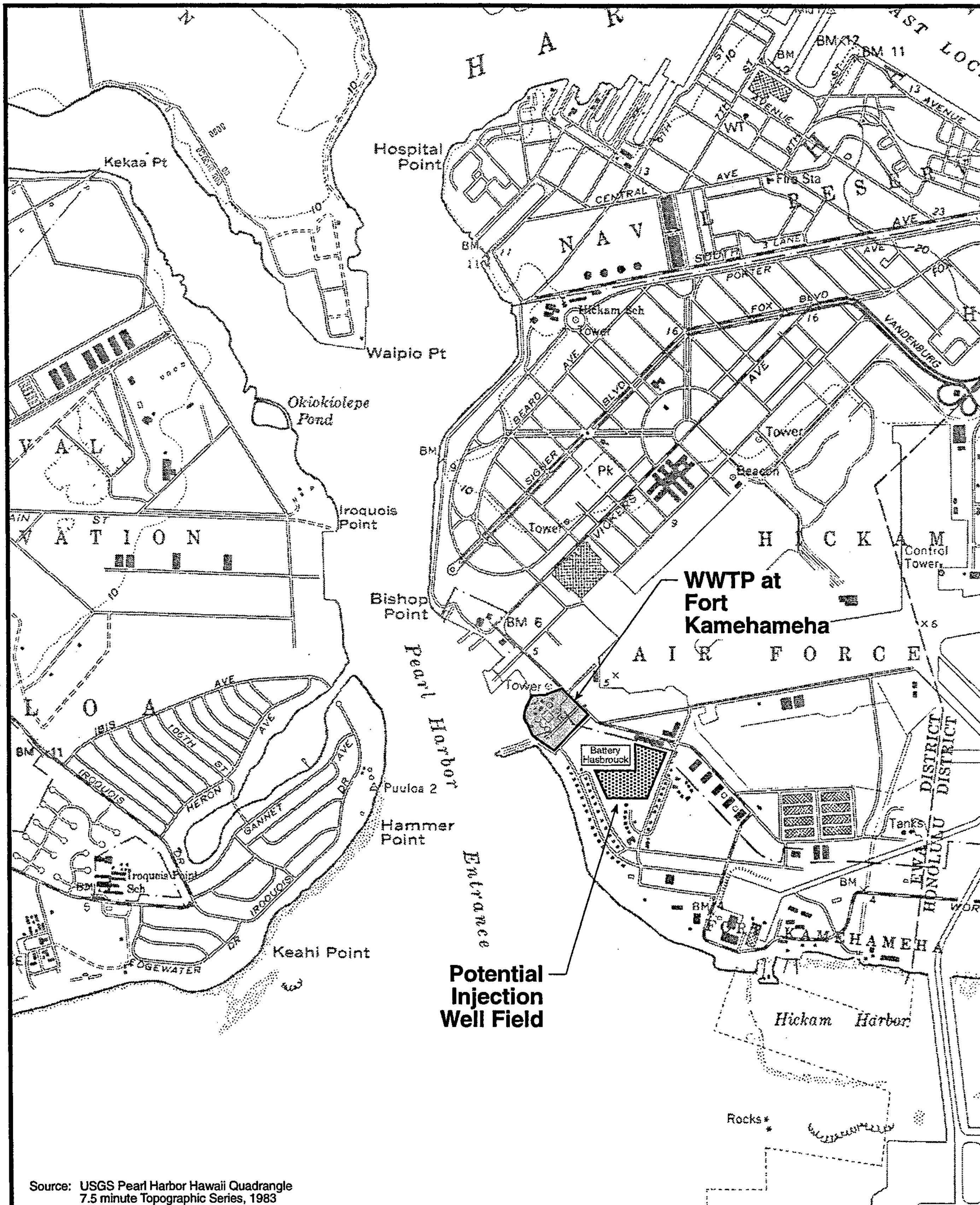


Source: USGS Pearl Harbor Hawaii Quadrangle 7.5 minute Topographic Series, 1983

NORTH

0 1000 2000
SCALE IN FEET
0 200 500m
SCALE IN METERS 1:24,000

LEGEND
WWTP at Fort Kamehemeha
Potential Injection Well Field

Figure 2.3-1
UNDERGROUND INJECTION ALTERNATIVE
EIS for Outfall Replacement, WWTP at Fort Kamehameha
March 2001

wells reducing the wells' disposal capacity. More aggressive cleaning methods, such as acid washing, may be required to maintain well capacity. When available methods are unable to restore capacity, additional wells would need to be drilled.

2.3.6 Construction, Operations, and Maintenance Costs

Overall, the 30-year life-cycle cost of an underground injection system for effluent from the WWTP at Fort Kamehameha is estimated to be $34.91 million. This includes projected initial costs of $13.44 million and annual O&M costs of $1.56 million. Table 2.3-1 summarizes costs for underground injection.

Table 2.3-1
Costs of Underground Injection

System Component	Capital/ Initial Cost	Annual O&M Cost	Present Value of O&M Cost for 30 Years	30-Year Life-cycle Cost
Chlorination System	$3,500,000	$300,000	$4,130,000	$7,630,000
Equalization Reservoir	$2,310,000	*	*	$2,310,000
Pumping System	$1,500,000	$400,000	$5,500,000	$7,000,000
Transmission & Distribution	$590,000	$10,000	$140,000	$730,000
Injection Wells & Backflush Systems	$5,540,000	$240,000	$3,300,000	$8,840,000
Monitoring & Compliance	**	$30,000	$410,000	$410,000
Administration & Overhead	**	$580,000	$7,990,000	$7,990,000
Total	$13,440,000	$1,560,000	$21,470,000	$34,910,000

* Operation and maintenance costs for the equalization reservoir are included in the operation costs for the transmission and distribution system.
** It is assumed that there would be no capital costs associated with monitoring and compliance or with administration and overhead.

2.3.7 Feasibility of Underground Injection

Although underground injection has a number of operational risks, its initial construction costs are competitive, even if life-cycle costs are not. Potential environmental impacts, including effects on wetlands, unknown effects of coastal water quality, and effects on archaeological remains, do not make this alternative infeasible without further analysis. This alternative is carried forward for more detailed evaluation of impacts in Chapter 4.

2.4 No-Action Alternative

This alternative consists of continuing to use the existing outfall for disposal of treated effluent from the WWTP at Fort Kamehameha. No repairs are currently planned for the existing outfall; however, this alternative assumes a one-time repair project would be implemented to address outfall deficiencies (see Section 1.2). Repair of the existing deficiencies would not affect permit compliance nor benefit the environment.

2.4.1 Receiving Environment

The existing outfall discharges into the Pearl Harbor Entrance Channel near the WWTP (see Figures 1.2-1 and 1.4-1). The receiving waters are classified by the DOH as Class 2 Inland Waters, which includes the entire Pearl Harbor Estuary. Because of the limited circulation of the estuarine waters and the nonpoint source pollution loading into Pearl Harbor from surrounding lands, the entire estuary is also classified by the DOH as a WQLS. The currently permitted ZOM for the existing outfall includes much of the Pearl Harbor Entrance Channel as well as a portion of the adjacent Open Coastal Waters (see Figure 1.2-1).

Although the existing discharge has not been shown to cause environmental degradation,[21] future increases in the quantity of effluent discharged will increase the loading to the estuary. The increased loading is prohibited and does not meet the objective of eliminating the discharge of wastewater effluent into the WQLS.

2.4.2 Regulatory Constraints and Requirements

This section identifies the permits and other regulatory constraints and requirements relevant to the no-action alternative.

2.4.2.1 Aquatic Environment

Rivers and Harbors Act

Under Section 10 of the Rivers and Harbors Act of 1899, performance of work or placement of any structure into or affecting navigable waters of the U.S. is permitted if it is recommended by the Chief of Engineers and authorized by the Secretary of the Army. A DA permit may be required for the repair of the existing outfall.

Clean Water Act

The existing discharge is permitted through the NPDES program administered by the DOH. The permit has expired and the existing discharge is authorized by an administrative extension. All conditions of the expired permit must be adhered to. The classification of Pearl Harbor Estuary as a WQLS signifies that an increase in point source nutrient loadings to the estuary will not be allowed. It is also anticipated that permit conditions regarding discharges into Pearl Harbor Estuary will become more stringent in the future (see Appendix I). Compliance under these circumstances would be problematic, and use of the existing outfall would limit the ability of the WWTP to accommodate future flow increases.

Coral Reef Protection

According to Executive Order 13089, dated June 11, 1998, federal agencies are required to identify which of their actions may affect U.S. coral reef ecosystems. Furthermore, they are required to utilize their programs and authorities to protect and enhance the conditions of any such ecosystems and, to the extent permitted by law, ensure that the actions they authorize, fund, or carry out will not degrade the conditions of the coral reef ecosystems. An increase in the pollutant loadings to the estuary may potentially impact existing coral habitat by degrading the

[21] Belt Collins & Associates (August 1992) *Expansion of the Wastewater Treatment Plant at Fort Kamehameha Environmental Assessment*. Prepared for the Department of the Navy, Public Works Center.

water quality (e.g., reduce dissolved oxygen concentration, introduce toxins, etc.) to a level such that coral may become less healthy or even die off in the affected areas.

2.4.2.2 Socioeconomics

Environmental Justice for Minority and Low-Income Populations

Executive Order 12898, issued on February 11, 1994, requires federal agencies to identify and address, as appropriate, the potential for disproportionately high and adverse environmental effects of its actions on minority and low-income populations. It is unlikely that the no-action alternative would have disproportionately high impacts on minority or low-income populations, because the people that typically use the area are not known to be members of a minority or low-income population.

2.4.3 Physical Description of No Action

The existing outfall is a 76-cm (30-inch) diameter pipe extending approximately 549 m (1,800 ft) in a westerly direction into the Pearl Harbor Entrance Channel. Effluent is discharged through a diffuser at a water depth of approximately 13.7 m (45 ft). Pumps are used to increase the pressure of the discharge and force effluent through the outfall during periods of high tides and/or high wastewater flows.

2.4.4 Construction Methodology

No new construction is proposed for the no-action alternative. Repair of the existing outfall would be accomplished by methods determined during planning and design of the repairs.

2.4.5 Routine Operations and Maintenance

Disinfected effluent from the WWTP normally discharges by gravity through the outfall pipe. If the flow rate is inadequate, pumps provide additional pressure to force flow through the outfall. System maintenance primarily involves maintenance of the effluent pump station equipment to ensure that the pumps will perform as required. The pumps are test-run weekly, lubricated and serviced quarterly, and repaired as required. No specific maintenance procedures are required for the outfall pipe itself.

2.4.6 Construction, Operations, and Maintenance Costs

2.4.6.1 Construction

There are no construction costs associated with the no-action alternative. For consistency with the cost analysis of the other alternatives, the estimated cost for repairing existing outfall damages (as described in Section 1.2) is included as a component of O&M costs discussed in Section 2.4.6.2.

2.4.6.2 Operations and Maintenance

Operational costs for the outfall consist of the energy costs associated with pumping the effluent through the outfall and monitoring receiving water quality. Currently, pumping is only required during extreme storm events that occur less than once per year. Monitoring costs for testing the

receiving water quality are the only routine operational expenses. Maintenance costs result from maintaining the effluent pump station. Outfall repair costs, which are assumed to occur during the first year, have been annualized over 30 years. These costs are summarized in Table 2.4-1.

Table 2.4-1
Operations and Maintenance Costs for the Existing Outfall

Activity	Quantity	Unit	Rate*	Total Cost
Effluent Pump Station O&M	20	worker-days/year	$270 ($/worker-day)	$5,400
Receiving Water Quality Sampling	20	worker-days/year	$270 ($/worker-day)	5,400
Receiving Water Quality Analysis	12	month/year	$2,325 ($/month)	27,900
Various Outfall Repairs	1	lump sum	$72,600/yr	72,600
Total Annual O&M Costs				$111,300

*The daily rate is based on a contract rate, which includes benefits and overhead.

2.4.6.3 Net Costs

The 30-year life-cycle cost of the no-action alternative is provided in Table 2.4-2.

Table 2.4-2
Cost Summary for the No-Action Alternative

System Component	Capital/Construction Cost	Annual O&M Cost	Present Value of O&M Cost for 30 Years	30-year Life-Cycle Cost
Existing Outfall	$0	$111,300	$1,533,000	$1,533,000

2.4.7 Feasibility of No Action

The no-action alternative is the least-cost alternative but fails to achieve the purpose of the proposed action, which is to reduce pollutant loadings from the wastewater discharge into the WQLS of the Pearl Harbor Estuary. Although less costly in the short term, the Navy would remain exposed to future uncertainties and penalties associated with its discharge permit, now pending renewal with DOH, and would ultimately be forced to reduce its discharge of pollutant loadings to the estuary. This alternative is carried forward for detailed comparison as required by the Council on Environmental Quality's regulations.

2.5 Treatment Plant Upgrade Alternative

This alternative considers the removal of additional pollutants from the effluent, such that the effluent being discharged from the existing outfall would comply with regulatory constraints for the 30-year life of the project. To provide for long-term disposal of effluent through the existing outfall, nutrients would need to be removed from the effluent as part of the treatment process. This would be necessary to meet the requirement to not increase nutrient loading to the Pearl Harbor Estuary. The existing WWTP has recently been upgraded and has been designed to reduce biochemical oxygen demand and suspended solids in the effluent such that the design flow of

49,000 m^3/day (13 mgd) can be discharged without increasing the discharge of these constituents over the levels discharged prior to the upgrade.

Although existing data indicates that the concentrations of toxic constituents in the effluent, specifically metals and chlorinated organics such as pesticides, are very low,[22] it is possible that future regulatory requirements may further limit the discharge of these constituents.

Removal of both nutrients and potentially toxic consti uents could be accomplished by a single process, such as reverse osmosis (RO)[23] or by fundamentally different separate processes for removal of nutrients and toxins. RO, as described for the reuse alternative in Section 2.7.3.2, would also remove salts from the effluent. For comparative purposes, this section will consider removal of nutrients by processes commonly used only for nutrient removal. It is possible that more stringent toxin removal will not be required during the 30-year project life; however, the risk that future regulations may require further toxin reduction for discharge into the Pearl Harbor Estuary would always be present.

2.5.1 Receiving Environment

The receiving environment for the treatment plant upgrade alternative would be identical to the receiving environment for the no-action alternative, as described in Section 2.4.1.

2.5.2 Regulatory Constraints and Requirements

This section identifies the permits and other regulatory constraints and requirements relevant to the treatment plant upgrade alternative.

2.5.2.1 Aquatic Environment

Rivers and Harbors Act

Under Section 10 of the Rivers and Harbors Act of 1899, performance of work or placement of any structure into or affecting navigable waters of the U.S. is permitted if it is recommended by the Chief of Engineers and authorized by the Secretary of the Army. A DA permit may be required for the repair of the existing outfall.

Clean Water Act

The existing discharge is permitted through the NPDES program administrated by the DOH. The permit has expired and the existing discharge is authorized by an administrative extension. The classification of Pearl Harbor Estuary as a WQLS signifies that an increase in point source nutrient loadings to the estuary will not be allowed. It is anticipated that permit conditions regarding discharges into Pearl Harbor Estuary will become more stringent in the future (see Appendix I).

The treatment plant upgrade alternative would need to produce effluent to meet future permit conditions, which are expected to require removal of nitrogen and phosphorus, and possibly of trace metallic and organic toxins.

[22]Most metals and pesticides are non-detectable in the effluent (see Section 4.8.2).

[23]Reverse osmosis is a type of membrane filtration process which purifies water by separating the water molecules from larger water molecules, such as dissolved salts.

2.5.2.2 Navigation

Federal Aviation Administration

Construction activities to upgrade the WWTP would occur in the vicinity of the Honolulu International Airport. Any construction activity near an airport is subject to FAA requirements. Under the FAA's Western Pacific Region, a Notice of Proposed Construction (permit number 7460-1) would have to be obtained. The FAA would distribute a NOTAM warning to aircraft using the airport. Depending on its location and height, construction equipment might directly impact flight lines at the Honolulu International Airport. The tops of the booms of any cranes would need to be shorter than 30 m (100 ft) and be flagged and lighted.

2.5.2.3 Protected Species and Habitats

Endangered Species Act

The ESA of 1973 requires that proposed actions do not jeopardize the existence of listed (endangered or threatened) plant and animal species. Section 7 of the Act requires that the USFWS, NMFS, or both agencies, be consulted when proposed federal actions may affect listed species or result in the destruction or adverse modification of critical habitat designated for such species. If the proposed construction areas for the new treatment plant facilities are found to contain listed species, ESA consultation would be required.

Magnuson-Stevens Act/Sustainable Fisheries Act

The treatment plant upgrade is not expected to impact any designated EFH or HAPC. The Magnuson-Stevens Act requires that the NMFS be consulted when a proposed federal action may adversely affect EFH or HAPC.

Coral Reef Protection

Under Executive Order 13089, dated June 11, 1998, federal agencies are required to identify their actions that may affect U.S. coral reef ecosystems, protect and enhance the conditions of coral reef ecosystems, and to the extent permitted by law, ensure that actions they authorize, fund, or carry out will not degrade the conditions of coral reef ecosystems. It is Navy policy to comply with Executive Order 13089 and to emphasize special considerations for coral reef protection and associated mitigation measures in the final environmental documentation of cases where significant adverse impact is likely.[24] An increase in the effluent discharge from the WWTP to the estuary, even with WWTP upgrade, may potentially impact existing coral habitat by altering the water quality such that coral may be impacted in the affected areas.

Protection of Wetlands

Executive Order 11988, issued May 24, 1977, directs federal agencies to avoid long-term and short-term adverse impacts associated with the destruction or modification of wetlands and to avoid direct or indirect support of new construction in wetlands. Depending upon location, construction activities for the treatment plant upgrade have the potential to impact wetland areas.

[24]Department of the Navy letter number 5090, Ser N45D/80589139, dated December 4, 1998, from Chief of Naval Operations regarding Coral Reef Protection Policy.

2.5.2.4 Cultural Resources

National Historic Preservation Act

The NHPA of 1966, as amended, and 36 CFR 800 (implementing regulations) requires federal agencies to consider the effects of their actions on historic properties. The SHPO in the DLNR would need to be consulted to determine means to avoid, reduce, or mitigate adverse effects on historic sites.

Native American Graves Protection and Repatriation Act

Signed into law in 1990, NAGPRA is intended to protect Native American (including Native Hawaiian) graves. The Act also provides for the inventory and repatriation of Native American human remains and associated funerary objects and addresses the conditions and circumstances when Intentional Excavation and Removal of Native American Human Remains and Objects is permitted. Regulations providing procedures are found at 43 CFR 10.3. If Hawaiian burials are encountered during construction, NAGPRA requires consultation with appropriate Native Hawaiian organizations.

2.5.2.5 Coastal Zone Management

The Hawaii CZM program, which has been approved by the U.S. Department of Commerce, is administered by DBEDT. Although the state's CZM program does not apply to lands and waters under federal ownership or exclusive control, consistency with the state's CZM program would be required due to potential spillover effects of the treatment plant upgrade alternative into nonfederal areas.

2.5.2.6 Socioeconomics

Environmental Justice for Minority and Low-Income Populations

Executive Order 12898, issued February 11, 1994, requires federal agencies to identify and address, as appropriate, the potential for disproportionately high and adverse environmental effects of their actions on minority and low-income populations. The potential for disproportionately high impacts on minority or low-income populations resulting from increasing effluent discharge into the Pearl Harbor Estuary would need to be identified and, if necessary, mitigated.

2.5.2.7 Other Regulatory Requirements

Floodplain Management

Executive Order 11988, issued May 24, 1977, provides floodplain management direction for federal agencies for avoiding to the extent possible the long-term and short-term adverse impacts of occupying and modifying floodplains, and for avoiding direct and indirect support of floodplain development whenever this is practical. Although new facilities required for the treatment plant upgrade would be located in floodplain areas, the alternative would be designed to minimize impacts on the floodplains. Impacts would also be mitigated through the use of BMPs and/or SOPs.

2.5.3 Physical Description of Treatment Plant Upgrade

2.5.3.1 Nutrient Removal

The removal of nutrients from wastewater can be accomplished by a variety of processes. These can be grouped into two main categories, biological processes and chemical-physical processes. Biological processes, as currently available, are generally capable of removing a high proportion of both nitrogen and phosphorous from wastewater. Chemical-physical processes, with the exception of RO, are generally specific to removal of either nitrogen or phosphorous. Development and implementation of biological nutrient removal processes within the past two decades has been motivated by a demand for processes that are less costly to operate than conventional physical-chemical processes and can be integrated into typical secondary treatment processes.

Because no increase in the discharge of either nitrogen or phosphorous into the waters of the Pearl Harbor Estuary is allowed, it was assumed that both nutrients would need to be removed from the effluent to continue discharging to the estuary. To develop both a planning level cost estimate and a space requirement estimate for nutrient removal at the WWTP at Fort Kamehameha, a range of available treatment technologies was considered.

The 5-Stage Bardenpho™ process was selected as a basis for O&M cost and space requirement estimates because of its relatively large number of installations worldwide and its proven ability to remove both nitrogen and phosphorous. This process uses a combination of anaerobic, anoxic, and aerobic stages to achieve biological nitrification and denitrification as well as phosphorous uptake and removal in the waste sludge. A schematic diagram of the process is provided in Figure 2.5-1.

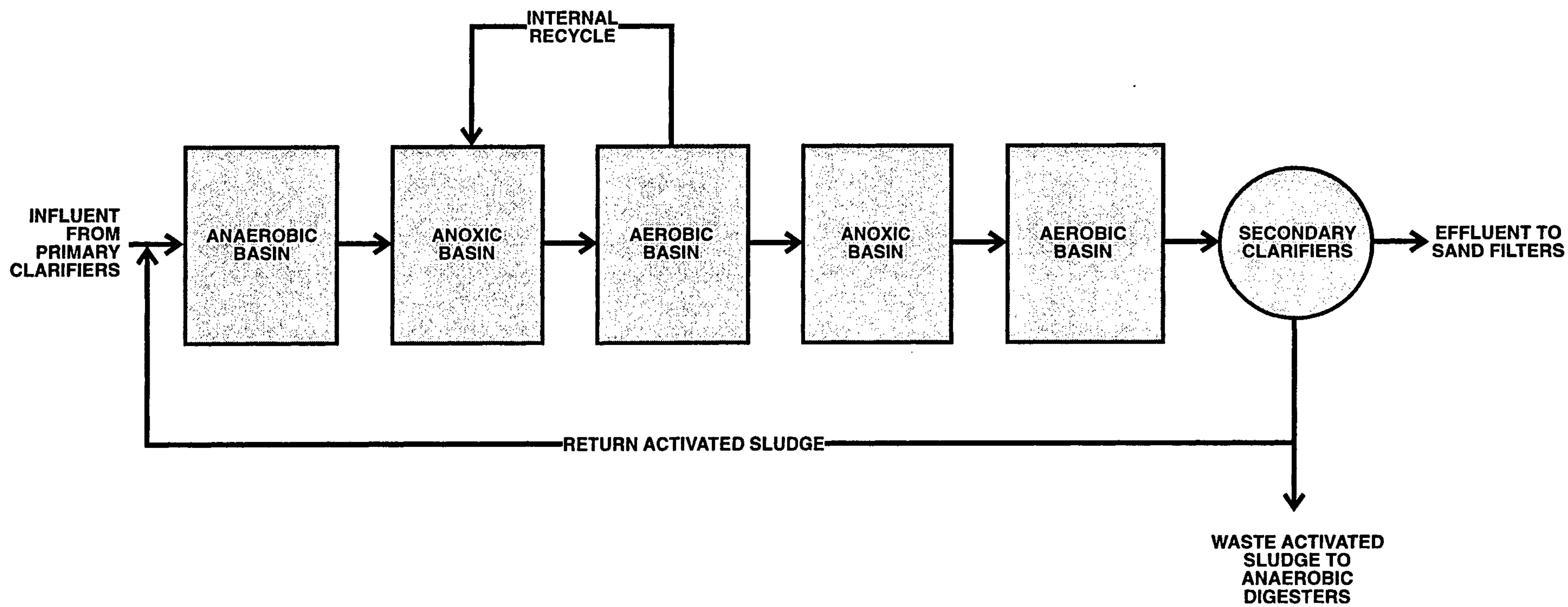
2.5.3.2 Removal of Trace Toxins

If required, these constituents could be removed from effluent by GAC filtration, following biological treatment for nutrient removal and sand filtration. Other approaches, such as increased source control, may also be effective for reduction of trace toxins in the effluent. As indicated in Section 2.5, above, RO would effectively remove most trace toxins in the effluent. However, as indicated in Section 2.7.6, the costs would be excessively high.

A GAC filtration facility sized to treat 49,000 m^3/day (13 mgd) of sand filtered secondary effluent would consist of either downflow or upflow activated carbon filters with the associated distribution piping, monitoring, and control equipment. Backwash would be returned to the head of the treatment plant. GAC would need to be replaced or regenerated on a periodic or continuous basis, depending on the specific process and equipment used.

2.5.3.3 Land Requirements and Siting

Preliminary sizing of a 5-stage Bardenpho™ process for removal of both nitrogen and phosphorous from a daily average wastewater flow of 49,000 m^3/day (13 mgd) has been estimated in order to determine the land area requirement to add this process to the WWTP at Fort Kamehameha. Space requirements for a GAC facility to treat 49,000 m^3/day (13 mgd) of sand-filtered secondary effluent has also been estimated. The total additional area required would be approximately 1.3 ha (3.2 ac). There is no space available on the existing WWTP site to locate these facilities.



Notes:
Aerobic - minimum dissolved oxygen=2.0 mg/l
Anoxic - oxygen-starved condition, dissolved oxygen near 0.0 mg/l
Anaerobic - sustained condition with dissolved oxygen = 0.0 mg/l

Figure 2.5-1
FIVE-STAGE BARDENPHO™ PROCESS FOR PHOSPHORUS AND NITROGEN REMOVAL

EIS for Outfall Replacement, WWTP at Fort Kamehameha
March 2001

Figure 2.5-2 shows four possible areas for site expansion; however, all are on Air Force land, and the necessary lands would need to be acquired for WWTP expansion.

With reference to Figure 2.5-2, each potential expansion site would present a number of constraints as identified in Table 2.5-1.

Table 2.5-1
Constraints of Various WWTP Expansion Sites

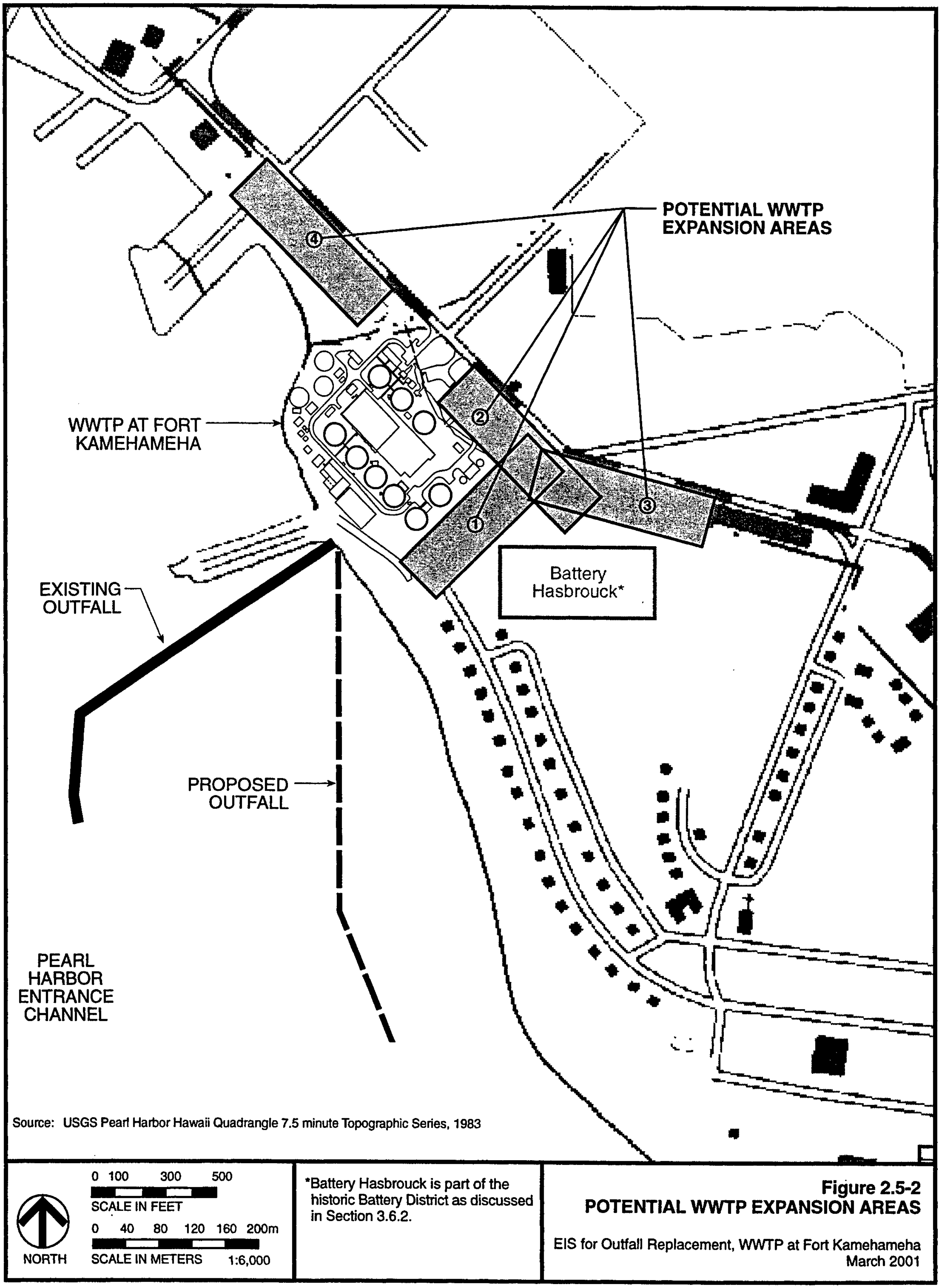
Site Number	Identified Site Constraints
1	• Displaces an area of known archaeological resources and human burials • Abuts the northwest corner of Battery Hasbrouck, an historic site • Is approximately 38 m (125 ft) from the nearest house • Requires diversion of approximately 90 m (295 ft) of a large drainage channel with identified wetland vegetation[25] • Requires diversion of existing maintenance roads
2	• Requires diversion of approximately 120 m (394 ft) of a large drainage channel with identified wetland vegetation[26] • Abuts the northern side of Battery Hasbrouck, an historic site • Abuts the southeast side of Fort Kamehameha Road • Requires diversion of an existing maintenance road • Could potentially impact archaeological resources and human burials
3	• Requires diversion of approximately 190 m (623 ft) of a large drainage channel • Abuts the northeast corner of Battery Hasbrouck, an historic site • Abuts the southeast side of Fort Kamehameha Road • Impacts an identified wetland area adjacent to the northeast corner of Battery Hasbrouck • Could potentially impact archaeological resources and human burials
4	• Requires the bridging of a major drainage channel for access and piping • Abuts the southeast side of Fort Kamehameha Road • Displaces a portion of an existing pier facility • Could potentially impact archaeological resources and human burials • Site of proposed Air Force marina complex

Battery Hasbrouck is part of the historic Battery District, as discussed in Section 3.6.2. With the exception of specific areas that have been fully surveyed (portions of sites 1, 2, and 3), areas in the vicinity of the WWTP have the potential to contain archaeological resources and human burials. Because of the large number of human burials already discovered in the vicinity of the WWTP site, any location proposed for WWTP expansion, with the exception of previously surveyed areas, would need to be thoroughly surveyed for archaeological resources and human burials prior to commencement of any expansion project.

2.5.4 Construction Methodology

Construction of the additional treatment units to provide biological nutrient removal and activated carbon filtration would be accomplished by conventional construction methods for industrial facilities and would be similar to the methods used for the recent upgrade of the WWTP. The site would require surface preparation prior to construction of footings, concrete pads, tanks, and other structures, which would be constructed according to the applicable design documents.

[25]Belt Collins & Associates (August 1992).
[26]Belt Collins & Associates (August 1992).



Source: USGS Pearl Harbor Hawaii Quadrangle 7.5 minute Topographic Series, 1983

*Battery Hasbrouck is part of the historic Battery District as discussed in Section 3.6.2.

Figure 2.5-2
POTENTIAL WWTP EXPANSION AREAS

EIS for Outfall Replacement, WWTP at Fort Kamehameha
March 2001

2.5.5 Routine Operations and Maintenance

O&M activities for nutrient and toxin removal facilities are similar to those for other treatment processes. Biological nutrient removal requires particular operator attention and monitoring during start-up and initial operational phases to optimize the process variables. Because wastewater characteristics differ from plant to plant and also change over time, operators need to implement strategies to determine the conditions under which treatment processes are optimized. The primary tasks involved would include:

- Transport and disposal of additional sludge.
- Routine process monitoring, including laboratory testing of samples for process control.
- Process adjustments, based upon monitoring results.
- Routine equipment inspections and servicing.
- Scheduled equipment repair and refurbishing.
- Routine GAC regeneration, replacement and disposal.
- Routine chemical acquisition, storage and feeding.
- Troubleshooting and responding to process upsets, equipment failures, etc.
- General site maintenance.

It is estimated that approximately six additional operators would be needed at the WWTP at Fort Kamehameha for operation of biological nutrient removal facilities, and that approximately four additional operators would be needed for operation of toxin removal facilities. The other major component of O&M costs would be energy consumption. It is estimated that approximately 5.4 million kilowatt hours (kWh) per year would be required for operation of nutrient removal facilities and approximately 0.7 million kWh per year would be required for operation of toxin removal facilities.

2.5.6 Construction, Operations, and Maintenance Costs

Because the information required to develop a planning level construction cost estimate for a 5-stage Bardenpho™ process was unavailable, three different construction and O&M cost estimates for nutrient and toxin removal facilities were developed for comparative purposes as follows:

- Construction cost estimate based on construction of a phosphorous removal plant in Nevada,[27] and an O&M cost estimate based upon estimates of labor, chemical, and electrical energy requirements for a typical biological nutrient removal system and a toxin removal system consisting of chemical coagulation prior to sand filtration with GAC filtration after sand filtration and prior to disinfection.

- Construction and O&M cost estimates based upon cost data presented for appropriate unit processes in *Handbook of Wastewater Treatment Processes*.[28]

- Construction cost estimate based on cost data presented in *Construction Costs for Municipal Wastewater Treatment Plants: 1973-1978*,[29] and an O&M cost estimate based upon estimates of labor, chemical, and electrical energy requirements for a typical biological nutrient removal

[27]PACNAVFACENGCOM working memorandum prepared in conjunction with Functional Analysis Concept Design package for project P-497, Extend Outfall, WWTP at Fort Kamehameha, October 26, 1993.

[28]Arnold S. Vernick and Elwood C. Walker (1981) *Handbook of Wastewater Treatment Processes*.

[29]U.S. Environmental Protection Agency (1980) *Construction Costs for Municipal Wastewater Treatment Plants: 1973-1978*. EPA/430/9-80-003.

system and toxin removal system. The toxin removal system would consist of chemical coagulation prior to sand filtration with GAC filtration after sand filtration and prior to disinfection.

The O&M component of each cost estimate includes a one-time repair project for the existing outfall that would be performed the first year. Based on the construction and O&M cost estimates, 30-year life cycle costs were calculated. Table 2.5-2 summarizes the cost estimates for providing nutrient removal and nutrient plus toxin removal at the WWTP at Fort Kamehameha.

Table 2.5-2
Cost of Nutrient and Toxin Removal

Level of Upgrade	Construction Cost	Annual O&M Cost	Present Value of O&M Cost for 30 Years	30-Year Life-Cycle Cost
Nutrient Removal*	$59,000,000	$1,207,000	$16,600,000	$75,600,000
Nutrient Removal**	$24,100,000	$3,313,000	$45,600,000	$69,700,000
Nutrient Removal***	$95,000,000	$1,207,000	$16,600,000	$111,600,000
Nutrient and Toxin Removal*	$68,000,000	$2,872,000	$39,500,000	$107,500,000
Nutrient and Toxin Removal**	$34,900,000	$5,703,000	$78,500,000	$113,400,000
Nutrient and Toxin Removal***	$104,000,000	$2,872,000	$39,500,000	$143,500,000

* Construction cost estimate based on construction of a phosphorous removal plant in Nevada, and an O&M cost estimate based upon estimates of labor, chemical, and electrical energy requirements for a typical biological nutrient removal system and a toxin removal system consisting of chemical coagulation prior to sand filtration with GAC filtration after sand filtration and prior to disinfection.

** Construction and O&M cost estimates based on cost data presented for appropriate unit processes in *Handbook of Wastewater Treatment Processes.*

*** Construction cost estimate based on cost data presented in *Construction Costs for Municipal Wastewater Treatment Plants: 1973-1978*; O&M cost estimate based upon estimates of labor, chemical, and electrical energy requirements for a typical biological nutrient removal system and a toxin removal system consisting of chemical coagulation prior to sand filtration with GAC filtration after sand filtration and prior to disinfection.

2.5.7 Feasibility of Treatment Plant Upgrade

The alternative to upgrade the WWTP at Fort Kamehameha to remove nutrients, with the option of an additional upgrade to remove toxins, has been determined to be an unreasonable alternative to the proposed action because of the following considerations:

- Additional WWTP land requirements of 1.3 ha (3.2 ac) (see Figure 2.5-2),
- 30-year life-cycle cost at least three times the comparable cost for the proposed outfall (approximately $21.6 million, see Section 2.2.6.3),
- Risk of more stringent future regulations,
- Impacts to wetland areas located in potential expansion sites,
- Potential for encountering archaeological resources and human burials during construction, and

- Does not meet the State's long-term goal of removing the discharge from the Pearl Harbor Estuary.

This alternative is not carried forward for a detailed comparison of impacts.

2.6 Infiltration and Evaporation

Although wastewater can be disposed of through infiltration and evaporation in land-based or aquatic systems, infiltration and evaporation is not a reasonable alternative for disposal of effluent from the WWTP at Fort Kamehameha due to the extremely large land requirement and potential for disrupting aircraft operations through the creation of favorable environments for birds. In addition, this alternative has the potential to disturb unknown archaeological and/or burial sites. As stated in Section 2.1.2.2, the conceptual design of the infiltration and evaporation alternative does not include the same level of detail as other alternatives. Upon determination of the land requirements this alternative was found to be infeasible, and further development of the conceptual design was deemed unnecessary.

Wastewater disposal systems using infiltration and evaporation generally provide a degree of natural wastewater treatment and are often used in lieu of mechanical/chemical/biological treatment processes. Wastewater systems using evaporation and percolation include: (1) slow-rate infiltration systems, (2) rapid-rate infiltration system, (3) rapid-rate percolation pipes, (4) constructed wetlands, and (5) aquatic ponds.[30] The basic characteristics of each of these systems is as follows:

- Slow-rate Infiltration. In a slow-rate infiltration system, wastewater is applied to vegetated land, meeting vegetation growth needs and disposing of the wastewater through evaporation, plant evapotranspiration, and soil percolation. Vegetation provides natural treatment for the wastewater, and slow-rate infiltration systems are often used with untreated or poorly treated wastewater. With rainfall around Fort Kamehameha averaging approximately 56 centimeters per year (cm/year) (22 inches/year), potential evapotranspiration averaging approximately 122 cm/year (48 inches/year), and soil permeability of approximately 380 cm/day (150 inches/day), disposal of WWTP effluent through slow-rate infiltration is estimated to require an area of approximately 435 ha (1,075 ac) or about three times the size of Ford Island.[31, 32, 33, 34]

- Rapid-rate Infiltration. In rapid-rate infiltration systems, pre-treated wastewater is applied to shallow, unvegetated infiltration basins. Because loading rates are high, most wastewater is disposed of through percolation rather than evaporation. The bottom of a rapid-rate infiltration system should not be less than 2 m (7 ft) and preferably at least 3 m (10 ft) above the water table.[35] A rapid-rate infiltration system for effluent from the WWTP at Fort Kamehameha would require approximately 215 ha (530 ac), with a ground surface elevation at least 3 m (10 ft) above the water table.

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[30]Metcalf & Eddy, Inc. (1991) *Wastewater Engineering: Treatment, Disposal, and Reuse*, Third Edition.

[31]Potential evapotranspiration calculated using the Thorthwaite Method (Source: Bras, Rafael L. [1990] *Hydrology*).

[32]National Oceanic and Atmospheric Administration, National Climatic Data Center (1995) *Climatological Data Annual Summary: Hawaii and the Pacific*. Volume 91 Number 13.

[33]U.S. Department of Agriculture, Soil Conservation Service in cooperation with the University of Hawaii Agricultural Experiment Station (August 1972) *Soil Survey of Kauai, Oahu, Maui, Molokai, and Lanai, State of Hawaii.*

[34]State of Hawaii, Department of Finance, Property Assessment Division, Tax Maps Section. Tax Maps: First Division, Plats 1-1-01 & 02 and Plat 9-9-01.

[35]Metcalf & Eddy, Inc. (1991).

- Rapid-rate Percolation Pipes. In subsurface percolation, wastewater drains to subsurface cavities or pipes where it percolates into surrounding materials. Subsurface percolation technologies such as leach fields are commonly used for wastewater systems serving individual residences or facilities. However, subsurface disposal can be used for larger wastewater treatment facilities. An underground percolation system for WWTP Fort Kamehameha would require at least 105 ha (260 ac) with ground surface elevations at least 5 m (16 ft) msl.

  A graveled percolation trench with buried perforated pipe has been proposed by the City for its Honouliuli WWTP (HWWTP), approximately 7.5 km (5 mi) west of the WWTP at Fort Kamehameha and across the Pearl Harbor Entrance Channel. To dispose of an average of 50,000 m^3/day (13.2 mgd) of treated effluent from the HWWTP, a City study estimated that the trench system would need to be about 3.5 km (2 mi) long and would cost approximately $14 million in 1995 dollars to construct, exclusive of land acquisition costs.[36]

  In contrast to conditions at the HWWTP, ground surface elevations over much of Hickam AFB and Fort Kamehameha are generally less than 5 m (16 ft) msl and surrounding areas are generally developed. If a subsurface percolation system were developed for the WWTP at Fort Kamehameha, effluent would need to be pumped to a higher elevation to avoid shallow groundwater. However, the nearest relatively undeveloped areas higher than 5 m (16 ft) msl are the Makalapa Crater and Halawa Interchange, approximately 2.4 km (1.5 mi) and 3.2 km (2 mi), respectively, from the WWTP.[37]

- Constructed Wetlands and Floating Aquatic Plants. Constructed wetlands are inundated land areas with water depths typically less than 0.6 m (2 ft) that support the growth of emergent plants. The plants provide surfaces for the attachment of bacterial films, aid in wastewater filtration, adsorb constituents in the wastewater, and oxygenate the water. Systems using floating aquatic plants are similar in concept to wetlands, except that floating plants are used for treatment and water depths are generally deeper than 1.8 m (6 ft). Wastewater disposal in these systems may occur through evapotranspiration; however, disposal may be augmented by surface, subsurface, or marine discharge, or by effluent reuse.[38] Due to high seasonal winter rainfall, wastewater disposal through evapotranspiration in a wetland or aquatic plant system would require approximately 3,000 ha (7,400 ac), equal to the area of Hickam AFB, Honolulu International Airport, and the U.S. Navy's Ewa Blast Zone combined.[39]

The 100 ha (250 ac) or more required for wastewater disposal through infiltration and evaporation do not exist in the southern portion of the Pearl Harbor basin. Even if land were available, acquisition at a commercial cost of about $1.5 million/ha ($600,000/ac) would require approximately $160 million for a subsurface percolation system, $320 million for a rapid-rate infiltration system, or $650 million for a slow-rate infiltration system. Table 2.6-1 summarizes land requirements and costs of wastewater through infiltration and evaporation. As shown in Table 2.6-1, this alternative is manifestly infeasible and is not further evaluated.

[36]City and County of Honolulu, Department of Wastewater Management (June 1995) *Honouliuli Reclamation and Reuse.*
[37]U.S. Geological Survey (1983) *Pearl Harbor, Hawaii Quadrangle.* 7.5 Minute Series (Topographic).
[38]Metcalf & Eddy, Inc. (1991).
[39]State of Hawaii, Department of Finance, Property Assessment Division, Tax Maps Section. Tax Maps: First Division, Plats 1-1-01, 02, & 03; Plats 9-1-01 and 10, Plat 9-3-02, and Plat 9-9-01.

Table 2.6-1
Effluent Disposal Using Infiltration and Evaporation

	System			
	Slow-Rate (Land Application)	Rapid-Rate (Infiltration Ponds)	Percolation Trench	Constructed Wetlands
Hydraulic Loading Rate in m^3/ha/day (gal/ac/day)	210 (22,500)	438 (46,800)	470 (50,300)	17.5 (1,870)
Required Area in ha (ac)	435 (1,075)	215* (530)	105** (260)	3,000 (7,400)
Approximate Land Cost at $1.5 million/ha ($600,000/ac)	$650 million	$320 million	$160 million	$4.5 billion
Approximate Areas of Federal Lands near Fort Kamehameha	Hickam AFB: 1,375 ha (3,398 ac) Honolulu International Airport: 1,050 ha (2,595 ac) Ford Island: 140 ha (346 ac) Waipio Peninsula, Navy Lands: 600 ha (1,483 ac) U.S. Navy Ewa Blast Zone: 1,040 ha (2,570 ac)			

* Entire area must be at least 3 m (10 ft) above msl.
** Entire area must be at least 5 m (16 ft) above msl.

2.7 Reuse Alternative

Treated wastewater effluent from the WWTP at Fort Kamehameha could potentially help meet nonpotable water irrigation needs in the Pearl Harbor area, thus reducing future demands on potable water sources. Effluent from the WWTP at Fort Kamehameha is saline and, in order to irrigate vegetation, would first need to be desalinated. In addition, to safeguard public health and protect the environment, effluent from the WWTP would need to be disinfected prior to reuse. RO could be used to desalinate and disinfect the effluent. New transmission infrastructure would be required to transport treated effluent from the WWTP to reuse sites. Underground injection wells would be installed to dispose of brine discharged from the desalination units, off-specification effluent, and wastewater in excess of reuse needs.

In lieu of desalination, the salinity of the effluent could be reduced through dilution with fresh water. However, approximately 490,000 m^3/day (130 mgd) of fresh water would be required to reduce the salinity of 49,000 m^3/day (13 mgd) of effluent to an acceptable level for irrigation.[40] Dilution is therefore considered impractical, as the nonpotable water demand for the entire island of Oahu was 485,000 m^3/day (128 mgd) in 1990.[41]

The 30-year life-cycle cost to desalinate, disinfect, and distribute effluent for reuse is estimated to be $179 million. However, effluent reuse could generate revenue through the sale of reclaimed water. As RO desalination would disinfect the reclaimed water, the cost of UV disinfection could be avoided. With all reclaimed effluent sold at BWS nonpotable rates and without the cost of UV

[40] Engineering Concepts, Inc. (March 1990) *Effluent Study for the Wastewater Treatment Facility at Fort Kamehameha, Pearl Harbor, Hawaii.* Prepared for the Department of the Navy, Public Works Center, Pearl Harbor, Hawaii.

[41] Wilson Okamoto & Associates, Inc. (May 1994) *Oahu Water Management Plan, Initial Revision of Technical Reference Document.* Prepared for City and County of Honolulu, Department of General Planning.

disinfection of effluent, the 30-year life-cycle cost for a reuse system would decrease to $117 million. Compared to the proposed replacement outfall's 30-year life-cycle cost of $21.6 million, effluent reuse is uneconomical.

2.7.1 Receiving Environment

There are two receiving environments for wastewater effluent under the reuse alternative. Approximately 75 percent of the effluent water would be transmitted to individual reuse sites. Brine from the desalination process would contain approximately 25 percent of the effluent water as well as virtually all nutrients and other dissolved constituents entrained in the effluent. Brine would be injected underground.

2.7.1.1 Receiving Environment: Reuse Sites

There is sufficient potential nonpotable water demand in the vicinity of Fort Kamehameha to reuse all desalinated effluent from the WWTP at Fort Kamehameha. As indicated in Section 2.7.3.2, approximately 36,800 m^3/day (9.7 mgd) of desalinated water could be produced from the 49,000 m^3/day (13 mgd) of WWTP effluent. The Hickam Mamala Bay Golf Course, Hickam Par 3 Golf Course, and Navy-Marine Golf Course each require approximately 3,000 m^3/day (0.8 mgd) of irrigation water on average. The nearby Honolulu International Airport requires approximately 36,000 m^3/day (9.5 mgd) of nonpotable water on average.[42] The U.S. Air Force owns the two Hickam golf courses, the Navy owns the Navy-Marine Golf Course, and the State Department of Transportation Airports Division owns the airport.[43] The airport is using nonpotable groundwater for irrigation needs and the Hickam Mamala Bay Golf Course will soon be doing so. Figure 2.7-1 shows potential reuse areas and conceptual effluent transmission facilities.

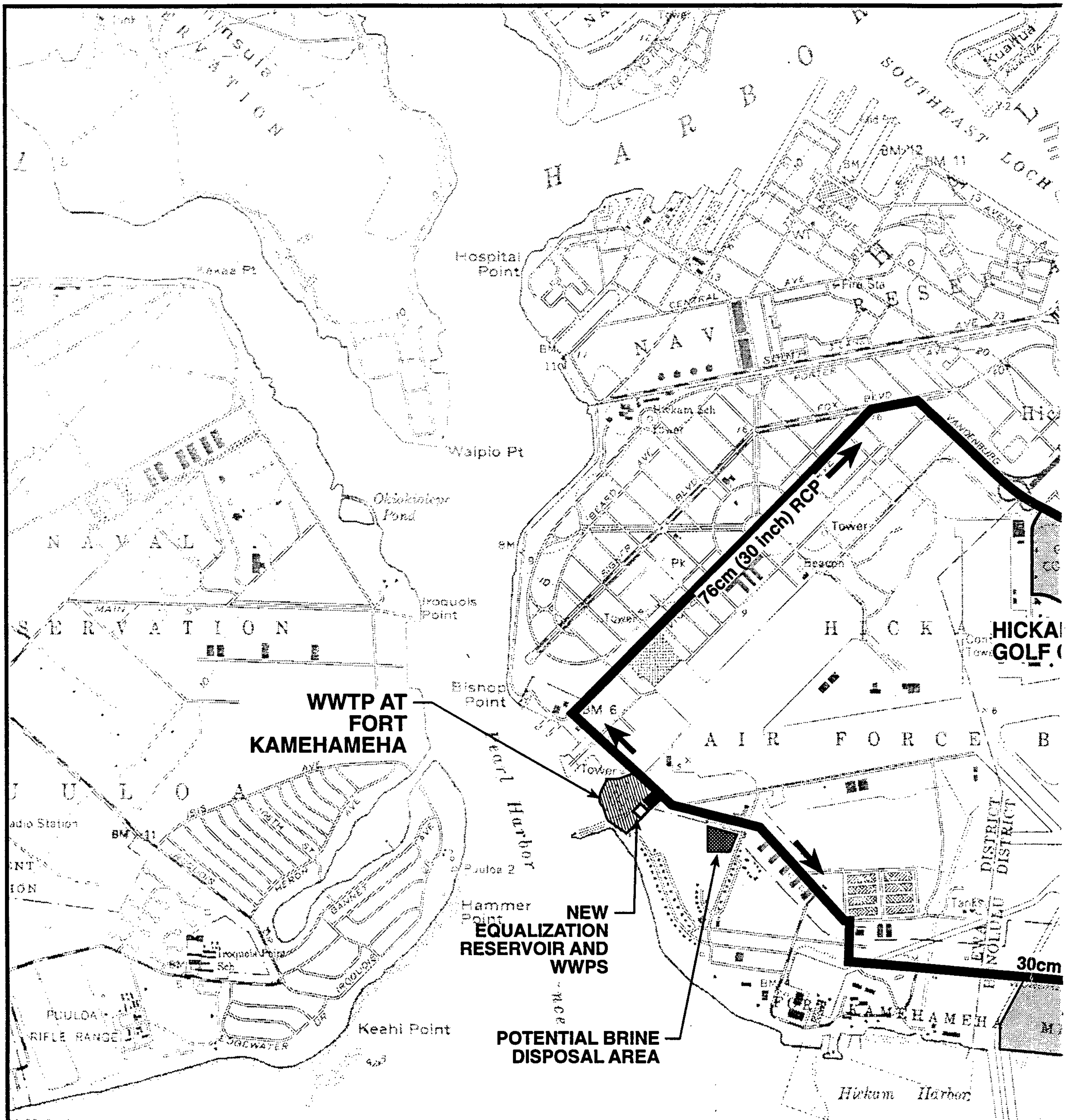
2.7.1.2 Receiving Environment: Desalination Brine

Desalination of the saline WWTP effluent would generate a brine containing virtually all of the effluent's sodium ions, chloride ions, nutrients, and other dissolved and suspended constituents. The brine would also contain up to 25 percent of the effluent's water. The brine must be either discharged to the ocean through a new outfall, injected underground, or disposed through percolation and evaporation. Continued use of the existing outfall for brine disposal is considered unfeasible as it would increase pollutant loadings into the Pearl Harbor Estuary, a Class 2 Inland Water body, with increased WWTP flows. Brine disposal by percolation and evaporation would also be impractical due to the large associated land requirement. Of the remaining two alternatives, disposal using underground injection wells would be more feasible economically than disposal through a new outfall, due to the quantity of water involved.

Desalination brine would be injected into the caprock formation which stretches for several miles along the southern Oahu coastline. See Section 2.3.1 for information regarding the injection well receiving environment. As indicated in Section 2.3.3, the proposed injection well field is located in an area identified as a jurisdictional wetland. All required permits would be obtained prior to construction.

[42]Belt Collins & Associates (December 1993a) *East Mamala Bay Wastewater Facilities Plan*. Prepared for the City and County of Honolulu, Department of Wastewater Management.

[43]State of Hawaii, Department of Finance, Property Assessment Division, Tax Maps Section. Tax Maps: First Division, Zone 1, Section 1, Plats 1, 2, 3, and 10.



Source: USGS Pearl Harbor, Hawaii Quadrangle, 7.5 minute Topographic Series, 1983

0 1000 2000 4000
SCALE IN FEET
0 250 500 1000m
SCALE IN METERS 1:24,000
NORTH

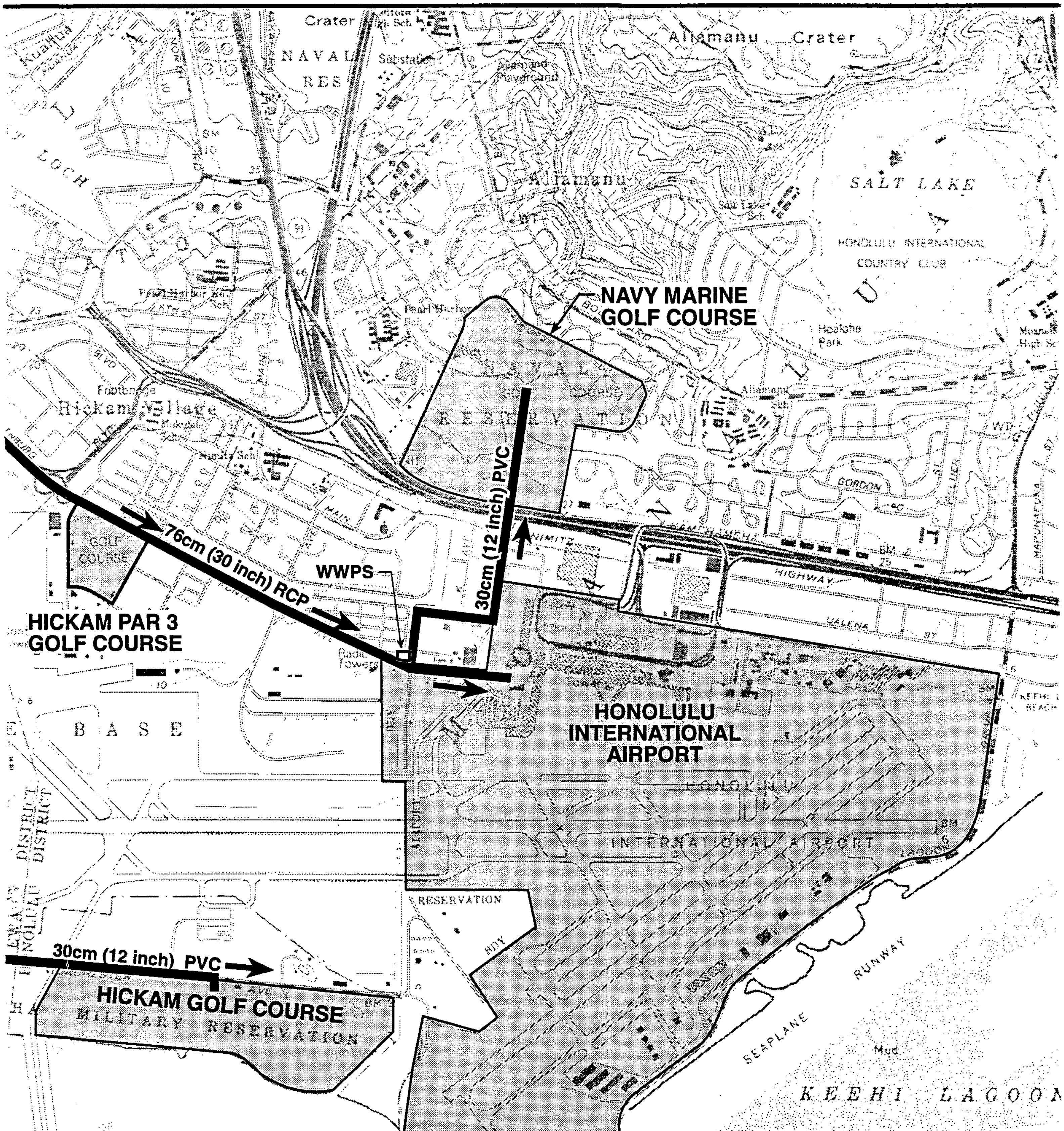
LEGEND

Potential Reuse Area

New Transmission Piping with Direction of Flow — 76cm / 30cm

WWPS New Wastewater Pumping Station

(1)



76cm (30 inch) RCP	76cm (30 inch) Diameter Reinforced Concrete Pipe
30cm (12 inch) PVC	30cm (12 inch) Diameter Polyvinyl Chloride Pipe

Figure 2.7-1
POTENTIAL IRRIGATION REUSE AREAS

EIS for Outfall Replacement, WWTP at Fort Kamehameha
March 2001

(2.)

2.7.2 Regulatory Constraints and Requirements

2.7.2.1 DOH Reuse Guidelines

The DOH Wastewater Branch regulates wastewater reuse to protect public health and the environment. The DOH's *Guidelines for the Treatment and Use of Reclaimed Water* (November 1993) defines levels of wastewater treatment, permissible uses for treated wastewater, and monitoring and reporting requirements. Additional requirements contained in HAR Chapter 11-62, "Wastewater Systems," are applicable to the use of reclaimed water on nonfederal lands only. The DOH regulates brine disposal from the desalination process, and other agencies regulate activities related to construction impacts.

Treatment Required for Wastewater Reuse

The allowable uses of reclaimed wastewater vary with degree of treatment. The DOH has defined three levels of wastewater treatment, identified as R-1, R-2 and R-3, that are suitable for different types of reuse application. All three levels of treatment require that wastewater initially be treated to a secondary level. Additional requirements for each of these three DOH-defined levels of treatment are as follows:

- <u>R-1—"Virtually Pathogen-Free" Effluent, Oxidized, Filtered, and Disinfected</u>. The disinfection process must reduce concentrations of a plaque-forming tracer virus to less than 1/10,000 of its initial concentration. The wastewater must be filtered prior to disinfection to remove suspended solids that could shield pathogens during disinfection.

- <u>R-2—Oxidized and Disinfected Effluent</u>. The concentration of fecal coliform bacteria must not exceed 50 colony-forming units per 100 milliliter for any sample. Filtration prior to disinfection is not required. Effluent from the WWTP at Fort Kamehameha is treated to an advanced secondary level, filtered, and disinfected.

- <u>R-3—Oxidized, Undisinfected Secondary Effluent</u>. For R-3 quality water, effluent must be treated to a secondary level as defined above. R-3 quality water does not have a disinfection requirement.[44] Effluent from the WWTP at Fort Kamehameha currently meets oxidation and suspended solids requirements for R-3 water. However, the effluent is too saline for irrigation use without desalination.[45]

If reused for irrigation, effluent from the WWTP at Fort Kamehameha would likely be treated to R-1 quality. The saline effluent must be desalinated prior to reuse, and RO desalination technology would disinfect as well as desalinate the effluent.[46]

Permissible Use of Reclaimed Effluent

Permissible uses of R-1, R-2, and R-3 quality water include surface, drip, or subsurface irrigation of fodder and seed crops, orchards, and food crops undergoing substantial processing before human consumption. Additional uses of R-1 and R-2 quality water include spray irrigation; irrigation of golf courses, freeways, and cemeteries; dust control; industrial processes; and concrete manufacture. R-1 quality water can be used in areas where the public has potential to contact the water, including the irrigation of public parks and athletic fields, commercial laundry

[44] State of Hawaii, Department of Health (November 1993) *Guidelines for the Treatment and Use of Reclaimed Water.*
[45] Metcalf & Eddy, Inc. (1991).
[46] Metcalf & Eddy, Inc. (1991).

water supply, toilet and urinal flushing, fire protection, decorative fountains, recreational impoundments, and washing of hard surfaces.[47]

Reclaimed water cannot be used near potable water supply wells or sprayed in a manner such that it could impact human health. R-1, R-2, and R-3 water cannot be applied within 15 m (50 ft), 30 m (100 ft), and 45 m (150 ft), respectively, of a drinking water supply well. R-1, R-2, and R-3 water cannot be impounded within 30 m (100 ft), 90 m (300 ft), and 300 m (1,000 ft), respectively, of a drinking water supply well.

Storage and Alternative Disposal Requirements

If reclaimed water is to be used for irrigation on nonfederal lands, HAR Chapter 11-62 and DOH guidelines require that an alternate disposal means or a temporary storage impoundment be provided. They must be able to accommodate wastewater flows in excess of irrigation needs and any treated wastewater of inadequate quality for irrigation reuse.

It is projected that the existing WWTP outfall would remain in service as an alternate disposal facility for effluent that cannot be reused due to inadequate irrigation demand or inadequate effluent quality. Because nutrients and other pollutants in the WWTP effluent would be concentrated in the desalination brine and discharged to the injection wells, excess reuse water could be discharged through the existing outfall, precluding the need for a wet weather storage impoundment.

If a replacement outfall is constructed at this time, it would not preclude future effluent reuse. The proposed replacement outfall could be potentially used for brine disposal as well as disposal of effluent in excess of reuse requirements.

Monitoring and Public Awareness Requirements

DOH guidelines require that detailed O&M, public education, employee training, and water quality monitoring plans be developed for areas where reclaimed wastewater is used. Monitoring wells and lysimeters[48] must be installed around irrigated areas, periodic water quality samples collected, and monitoring reports submitted to the DOH. Signs must be posted around reuse areas advising the public that reclaimed water is being used and the appropriate measures to take if contact occurs. Employees working around reclaimed water need to be educated about potential health risks and the precautions to be taken in their work.[49]

2.7.2.2 Desalination for Irrigation

Effluent from the WWTP at Fort Kamehameha is highly saline, with chloride concentrations generally ranging from 3,500 mg/l to 5,500 mg/l.[50] Its high concentrations of sodium and chlorides preclude its reuse for irrigation without desalination. Irrigating without desalination can kill plant life, lead to harmful accumulations of salts and minerals in soils, adversely impact soil permeability, and deteriorate irrigation delivery systems. For general irrigation needs, the concentration of chlorides in irrigation water should be below 300 mg/l.[51]

[47]State of Hawaii, Department of Health (November 1993).
[48]A lysimeter is a subsurface container that collects water percolating through the root zone.
[49]State of Hawaii, Department of Health (August 1991).
[50]U.S. Navy, Pacific Division, Naval Facilities Engineering Command (1996).
[51]Metcalf & Eddy, Inc. (1991).

2.7.2.3 Brine Disposal Regulations

Underground injection of desalination brine is regulated under HAR Title 11, Chapter 23, "Underground Injection Control" (UIC). The caprock aquifer into which brine would be injected is an "exempted" aquifer, one which the DOH has excluded as underground source of drinking water.[52] Specific regulatory requirements for the siting, design, construction, and operation of injection wells are discussed above in Section 2.3.2.

It is assumed that the existing WWTP outfall could be used as a backup disposal system for the injection wells. With the existing outfall only used for backup purposes, discharges to the Pearl Harbor Estuary would only occasionally occur with a corresponding decrease of WWTP pollutant loadings from existing conditions.

2.7.2.4 Other Regulatory Requirements

Federal Aviation Administration

Construction activities for a reuse system would occur in the vicinity of the Honolulu International Airport. Any construction activity near an airport is subject to FAA requirements. Under the FAA's Western Pacific Region, a Notice of Proposed Construction (permit number 7460-1) would have to be obtained. The FAA would distribute a NOTAM warning to aircraft using the airport. Depending on its location and height, construction equipment might directly impact flight lines at the Honolulu International Airport. The booms of any cranes would need to be flagged and lighted and could not exceed 30 m (100 ft) in height.

Endangered Species Act

Because construction activities would take place in developed areas, they would not be expected to jeopardize the continued existence of any endangered or threatened species. However, Section 7 of the ESA of 1973 requires consultations with the USFWS, the NMFS, or both agencies, when proposed federal actions may affect listed (threatened or endangered) species or result in the destruction or adverse modification of critical habitat designated for such species. If any area(s) proposed for construction of reuse facilities contain listed species or are designated critical habitat for such species, ESA consultation would be required.

Magnuson-Stevens Act/Sustainable Fisheries Act

The reuse alternative is not expected to impact any designated EFH or HAPC. The Magnuson-Stevens Act requires that the NMFS be consulted when a proposed federal action may adversely affect EFH or HAPC.

Protection of Wetlands

Executive Order 11990, dated May 24, 1977, directs federal agencies to avoid long-term and short-term adverse impacts associated with the destruction or modification of wetlands, and to avoid direct or indirect support of new construction in wetlands. Construction activities associated with the reuse alternative have the potential to damage wetland areas, depending on the site location.

[52] State of Hawaii, Department of Health (September 1992).

Cultural Resources

Section 106 of the NHPA of 1966 and 36 CFR 800 require federal agencies to consider the effects of their actions on historic sites. The SHPO would need to be consulted to determine means to avoid or minimize adverse impacts on historic sites.

Signed into law in 1990, NAGPRA is intended to protect Native American (including Native Hawaiian) graves. It provides for the inventory and repatriation of Native American human remains and associated funerary objects and addresses the conditions and circumstances when Intentional Excavation and Removal of Native American Human Remains and Objects is permitted. Regulations providing procedures are found at 43 CFR 10.3. If Hawaiian burials are encountered, NAGPRA requires consultations with appropriate Native Hawaiian organizations.

Coastal Zone Management

The Hawaii CZM program, which has been approved by the U.S. Department of Commerce, is administered by DBEDT. Although the state's CZM program does not apply to lands and waters under federal ownership or exclusive control, consistency with the state's CZM program would be required for reuse facilities on land at and near the Honolulu International Airport that is not under federal control. Construction activities for the reuse system within the CZM area would require coordination with state and local agencies.

Flood Plain Management

Executive Order 11988, issued May 24, 1977, provides floodplain management direction for federal agencies for avoiding to the extent possible the long-term and short-term adverse impacts of occupying and modifying floodplains, and for avoiding direct and indirect support of floodplain development whenever this is practical. Although some reuse sites would be located in floodplain areas, the alternative would be designed to minimize impacts on the floodplains. Impacts would also be minimized through the use of BMPs and/or SOPs.

Environmental Justice for Minority and Low Income Populations

Executive Order 12898, issued February 11, 1994, requires federal agencies to identify and address, as appropriate, the potential for disproportionately high and adverse environmental effects of its actions on minority and low-income populations. Therefore, the impacts on minority and low-income populations would be identified and mitigated, if necessary.

2.7.3 Physical Description of Reuse Facilities

To protect public health, preserve irrigated landscaping, and prevent damage to equipment, effluent from the WWTP at Fort Kamehameha must be treated to R-1 quality and desalinated prior to reuse as irrigation water. Current wastewater treatment facilities at Fort Kamehameha have the potential to produce R-1 quality effluent. However, without costly additional treatment, wastewater salinity would kill any irrigated landscaping. Consequently, additional treatment facilities would be needed to desalinate the effluent and to ensure the production of R-1 quality water.

At the WWTP, a new short-term storage impoundment, or equalization reservoir, would be required to retain reclaimed water for use until needed. This storage impoundment would equalize diurnal flows of wastewater and irrigation demand but would not be used for effluent in excess

of the daily demand for reclaimed water or for effluent of inadequate quality. From the WWTP, new transmission infrastructure would convey the desalinated and disinfected effluent to individual reuse areas. Existing distribution infrastructure within each of the reuse areas would have to be modified to use reclaimed water. Finally, groundwater monitoring wells and lysimeters would need to be installed in these areas and signs posted advising the public that reclaimed water is in use.[53]

2.7.3.1 Wastewater Treatment Facilities

Effluent from the WWTP at Fort Kamehameha generally meets DOH treatment standards for five-day biochemical oxygen demand, total suspended solids, and pH.[54] Major components necessary to produce R-1 quality water, such as aeration, sedimentation, filtration, and disinfection facilities, are present at the WWTP at Fort Kamehameha. However, production of R-1 effluent would be subject to additional monitoring and possibly would require modification of plant facilities and/or operations.

2.7.3.2 Desalination Treatment Facilities

As discussed in Section 2.7.2.2, current chloride concentrations in the effluent range between 3,500 mg/l and 5,500 mg/l, too high to use for irrigation.[55] Desalination could reduce chloride concentrations to meet irrigation water requirements. However, an approximately 80 percent reduction from current levels to about 1,000 mg/l may be acceptable for irrigation of certain plants.[56] Desalination of the effluent is discussed below.

Desalination Technology

There are three general types of desalination technology: phase change, ion exchange, and membrane. RO and electrodialysis reversal (EDR), both membrane technologies, are generally used for large-scale, land-based desalination. Although phase change technologies are widely used for shipboard desalination and ion exchange technologies are widely used to create ultra-pure water, the former has a large energy requirement and the latter a large chemical requirement, rendering both uneconomical for large-scale desalination.[57] Because the energy requirements for the EDR processes increase directly with salinity, RO desalination is generally more cost effective than EDR when the total dissolved solids concentration exceeds 3,000 mg/l, such as at Fort Kamehameha.[58]

Desalination Equipment

A conceptual RO desalination system for the WWTP at Fort Kamehameha would include a flow equalization basin, pretreatment chemical addition and pH adjustment, high-pressure feed pumps, and RO membranes. With a wastewater inflow of 49,000 m^3/day (13 mgd) and a recovery rate of 75 percent, the RO desalination system would produce approximately 36,800 m^3/day (9.7 mgd)

[53]State of Hawaii, Department of Health (November 1993).

[54]State of Hawaii, Department of Health (November 1993; U.S. Navy, Pacific Division, Naval Facilities Engineering Command (1996).

[55]U.S. Navy, Pacific Division, Naval Facilities Engineering Command (1996).

[56]Metcalf & Eddy, Inc. (1991).

[57]CH2M Hill (August 1985) *Proposed Demonstration Desalting Plant, Volumes 1 and 2.* Prepared for the State of Hawaii, Department of Land and Natural Resources Report R-74; Holmes & Narver, Inc. (June 1974) *Water Desalting in Hawaii.* Prepared for the State of Hawaii, Department of Land and Natural Resources.

[58]CH2M Hill (August 1985); Holmes & Narver, Inc. (June 1974).

of reclaimed water for irrigation. Chemicals would be added prior to entry of wastewater to the RO units, to inhibit membrane scaling and adjust effluent pH.

Land Requirement for the Desalination System

The additional treatment facilities for effluent reuse would require approximately 1 ha (2.5 ac) and would need to be located on vacant land around the existing WWTP facilities. Of the 1 ha (2.5 ac), the flow equalization basin would require approximately 0.35 ha (0.9 ac).

2.7.3.3 Disinfection Facilities

As the general public might be present while reclaimed effluent is being used for irrigation, the effluent must be disinfected in accordance with DOH guidelines for R-1 quality water. The RO membranes would remove pathogens, likely disinfecting the effluent to an R-1 level at the same time as desalination. Pathogens removed by the process would be discharged with the reject brine. The UV system recently installed at the WWTP could be used for brine disinfection along with the addition of sufficient chlorine to prevent biological growth which could clog the injection wells. With DOH approval, only the reject brine would need to be passed through the UV disinfection process, reducing the overall UV disinfection requirement at the WWTP by about 75 percent.

2.7.3.4 Transmission Infrastructure for Reclaimed Effluent

New transmission infrastructure would be required to convey treated effluent from the WWTP to individual reuse areas. As conceived, a 36,800 m^3 (9.7 million gallon [gal]) reservoir would be used for storage of desalinated, disinfected effluent. Because most irrigation demand is at nighttime, this reservoir would store effluent until required by users. As identified in Section 2.7.2.1, excess effluent would be discharged through the existing outfall. A new pumping station would draw treated wastewater from the reservoir and pump it via an approximately 3.0-km (1.9-mi)-long, 30-cm (12-inch)-diameter polyvinyl chloride (PVC) main to the Hickam Mamala Bay Golf Course. The pumping station would also feed an approximately 6.1-km (3.8-mi)-long, 76-cm (30-inch)-diameter reinforced concrete pipe (RCP) main to the Hickam Par 3 Golf Course and the Honolulu International Airport. A second new booster pumping station near the airport would draw effluent from the 76-cm (30-inch) RCP main and pump it to the Navy-Marine Golf Course via a 2.2-km (1.4-mi)-long, 30-cm (12-inch)-diameter PVC main. Transmission lines would be routed along existing roadways wherever possible, and pumping and storage facilities would be located on vacant Air Force- or Navy-owned land. Figure 2.7-1 shows transmission infrastructure.

2.7.3.5 Distribution Infrastructure for Reclaimed Effluent

Existing irrigation systems at the golf courses and the Honolulu International Airport could be used for effluent application. However, the existing systems would need to be retrofitted to prevent inappropriate use of the reclaimed effluent and cross-connection with other water or wastewater systems. The systems using reclaimed water would need to be completely separated from other domestic water supply systems. Components would need to be clearly marked to indicate that reclaimed water was being distributed and appurtenances modified to prevent inappropriate use. Section 2.7.4 further discusses the construction activities for retrofitting existing nonpotable water systems.

2.7.3.6 Brine Disposal Infrastructure

Desalination brine would be pumped to two new 50-cm (20-inch)-diameter injection wells on vacant land east of the WWTP. An approximately 500-m (1,640-ft)-long, 91-cm (36-inch)-diameter pipeline would be required to convey effluent from the WWTP to the wells. New low-pressure booster pumps would be required to pump the water through the line. If the shallow limestone layer under the WWTP extends to a depth of at least 80 m (260 ft), the new injection wells should be solid cased for their first 30 m (100 ft) and left open for the remaining 50 m (160 ft). The anticipated well casing is 35-cm (14-inch) PVC. The wells would need to be spaced at least 30 m (100 ft) apart. To help remediate future well degradation, a backflush system would be installed for each. Similarly, as nutrients can cause biological growth in wells and permanently impair well capacity, the brine should be chlorinated to mitigate nutrient growth and preserve well capacity. As the existing WWTP chlorination facility has been decommissioned, a new chlorination facility would have to be constructed as a part of the brine disposal system.

2.7.3.7 Monitoring and Compliance Infrastructure

Under DOH guidelines, nine new monitoring wells and seven lysimeters would need to be installed for the purposes of monitoring groundwater quality. Each of the four reuse sites would require one upgradient or crossgradient monitoring well and one downgradient monitoring well. A reuse site such as the airport, which covers more than 400 ha (1,000 ac), would require an additional downgradient monitoring well. With one lysimeter installed for every 80 ha (200 ac) of irrigated area, the two Hickam golf courses would need one each, the Navy-Marine Golf Course two, and the airport three. The DOH may adjust the required number of lysimeters and monitoring wells to address public health or environmental protection concerns.[59]

Signs would have to be posted within each reuse area stating that reclaimed water was being used and that it was not for drinking.[60]

2.7.4 Construction Methodology

Construction activities for effluent reuse from the WWTP at Fort Kamehameha would include clearing, grading, excavation, trenching, erection of new structures, and installation of modular pumping and treatment units. In general, construction activities for treatment, transmission, distribution, and monitoring and compliance infrastructure could proceed independently.

2.7.4.1 Treatment Facilities

Construction of additional treatment facilities would be limited to the immediate vicinity of the WWTP at Fort Kamehameha. General site work for the entire facility would include clearing, finish grading, drainage improvements, paving of new access roads, and perimeter fencing. Pumps, chemical addition units, and desalination units would likely be modular, minimizing on-site fabrication requirements.

Construction of a new flow equalization basin for the desalination facility would generate approximately 11,000 m^3 (14,400 yd^3) of material. This material must be dewatered and hauled off site for disposal. As excavated material could likely be dewatered within the excavation of the flow equalization basin, dewatering effluent would not need to be discharged off site.

[59]State of Hawaii, Department of Health (November 1993).
[60]State of Hawaii, Department of Health (November 1993).

2.7.4.2 Transmission Infrastructure

Construction of new transmission infrastructure would involve a new storage reservoir, two new pump stations, and transmission lines to reuse areas. Construction of a storage reservoir would be similar to construction of the flow equalization basin for the desalination plant. Excavated material from the center of the reservoir could possibly be used to build the berms around the outside. Construction of the new pump stations would require general site clearing, limited grading, construction of a new structure and booster pump pads, installation of pumps and piping, and perimeter fencing.

New transmission lines along roadways, primarily within Hickam AFB (see Figure 2.7-1), could be constructed using conventional trenching methods or micro-tunneling. For trenching, the contractor would excavate a section of trench, install the pipe and bedding, backfill the trench, and repave the road. Microtunneling would limit surface construction activities to access pits approximately every 100 m (330 ft) along the transmission main alignments and staging areas.

2.7.4.3 Distribution Infrastructure

Although it is proposed that the existing nonpotable distribution infrastructure be used within the golf courses and airport, these nonpotable systems must be retrofitted to be completely separate from other water supply systems. Appurtenances may need to be modified to prevent inappropriate use of the reclaimed water and measures implemented to prevent cross-connection with other utilities. Based on DOH Guidelines for effluent reuse, construction activities to retrofit existing systems for irrigation reuse would include the following:

- Distribution System Isolation. Distribution systems for reclaimed effluent must be completely separated from other water supply systems.

- Marking of Distribution System Components. To prevent inappropriate use of reclaimed water or inadvertent cross-connections to the reclaimed water system, all aboveground components of the reclaimed system must be clearly marked.

- Additional Considerations. Distribution reservoirs must have signs indicating that reclaimed water is impounded and that it should not be touched or drunk. Any hose bibs on the existing systems converted to reclaimed use should be retrofitted with couplers that are different from those on the potable system.[61]

2.7.4.4 Brine Disposal Infrastructure

Wells would be drilled using either a rotary or cable tool method. Drilling rigs would not exceed the 30-m (100-ft) height limit set by airfield operations. The new transmission and backflush lines would be constructed using either trenching or micro-tunneling. The new booster pumps would require some site preparation, construction of booster pump pads, and installation of the booster pumps. The chlorination facility could be incorporated into the booster pump facility with a chlorine cylinder crane and loading area, chlorine storage area, and installation of injection and monitoring equipment.

[61]State of Hawaii, Department of Health (November 1993).

2.7.4.5 Monitoring and Compliance Infrastructure

Each of the nine new monitoring wells would be drilled using a drilling rig and developed using a bailer or pump. Each of the seven lysimeters would be fabricated before being brought on site. Installation would require excavation, backfilling of the excavation, and sod restoration.[62]

Signs would need to be posted within each reuse area advising the public that reclaimed water is being used for irrigation and that it is not to be ingested.[63]

2.7.4.6 Schedule

If construction of new facilities and retrofitting of existing distribution facilities occurred simultaneously, the construction process could be completed in about 24 months. Required construction times for specific components of the reuse system are as follows:

- <u>New Treatment Facilities</u>. Construction of new treatment facilities, including pumps, desalination units, and a flow equalization basin, is estimated to require 18 to 24 months.

- <u>New Transmission Infrastructure</u>. Construction of new transmission infrastructure would likely require at least six months.

- <u>Distribution Infrastructure</u>. Retrofitting of each existing irrigation distribution system would take three to six months.

- <u>Underground Injection Wells for Brine Disposal</u>. Construction of each well is projected to require approximately 30 days. The booster pumps and piping could be built in less than two months.

- <u>Monitoring and Compliance Infrastructure</u>. Installation of monitoring and construction infrastructure would require four to six months.

2.7.5 Routine Operations and Maintenance

In general, the additional facilities required for effluent reuse can be operated and maintained in conjunction with the existing WWTP and existing distribution systems. Reuse would increase energy consumption for wastewater treatment due to desalination.

2.7.5.1 Additional Treatment Systems

The desalination systems required to reclaim effluent for irrigation reuse would increase electrical power consumption, staffing requirements, and maintenance needs at the WWTP. It is estimated that desalination would require approximately 39 million additional kilowatts of electricity each year. Routine O&M activities would include chemical addition to inhibit RO descaling, RO membrane cleaning, and servicing of moving parts. RO membranes would need to be changed every few years.

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[62]State of Hawaii, Department of Health (November 1993).
[63]State of Hawaii, Department of Health (November 1993).

2.7.5.2 Transmission System

The transmission system can be operated from the WWTP at Fort Kamehameha. Routine maintenance for the system would include upkeep of the flow-equalization basin and periodic servicing of booster pumps. After approximately 10 years, booster pumps should be overhauled.

2.7.5.3 Distribution System

Distribution system operations with reclaimed water would be similar to existing irrigation system operations. However, any restrictions on the use of reclaimed water would need to be listed near irrigation system controllers. Public advisory signs stating that reclaimed water is in use would have to be maintained.

2.7.5.4 Disposal of Desalination Brine

Routine O&M for injection wells would include pumping water to the wells and backflushing to remove accumulated sediments and bacterial growth. Desalination brine should pass through the recently completed UV disinfection system at the WWTP to minimize sediments and microorganisms that could potentially clog injection wells. A chlorination facility would also be operated.

2.7.5.5 Monitoring and Compliance

Prior to implementing an irrigation program using reclaimed water, the DOH requires that detailed plans for irrigation, O&M, public education, employee training, and water quality monitoring be developed and implemented for reuse areas. Employee training and awareness programs must be implemented, and baseline groundwater quality samples collected. For reuse on nonfederal lands, the DOH approves each plan and generally requires a report on construction and implementation.[64]

2.7.6 Construction, Operations, and Maintenance Costs

To enable an economic comparison with the proposed action and other alternatives, a 30-year life-cycle cost was calculated for effluent reuse. However, to assess the economic viability of reclaimed water relative to other sources of irrigation water, a unit cost was also calculated, reflecting the cost of producing one cubic meter of water.

2.7.6.1 30-Year Life-Cycle Cost

The cost to reuse effluent from the WWTP at Fort Kamehameha would include desalination, transmission to reuse areas, modification of irrigation distribution systems, compliance with DOH regulations, and O&M. For the purposes of comparing effluent reuse with other alternatives, only additional costs associated with required upgrades for effluent reuse were considered in calculating the 30-year life-cycle cost. Costs assumed that the existing outfall could continue to be used with no modification. Additionally, the costs associated with effluent reuse could be partially offset through the sale of the reclaimed water and the avoided cost of not using UV disinfection for wastewater passing through the RO membranes. Assuming that all water can be sold and the price of nonpotable water remains constant, the sale of 36,800 m^3/day (9.7 mgd) at

[64]State of Hawaii, Department of Health (November 1993).

the current BWS nonpotable rate of $0.30/m^3 ($1,135/million gal) would net approximately $4.0 million per year.

Allowing for the avoided cost of UV disinfection and the revenues from the sale of water, the initial cost for effluent reuse is estimated to be $63.6 million with a 30-year life-cycle cost of $117.1 million. The energy requirement for effluent reuse is estimated to be 41.25 million kWh per year or about 68,700 barrels of oil per year. Table 2.7-1 summarizes costs for effluent reuse and Table 2.7-2 presents projected energy consumption.

Table 2.7-1
Cost of Effluent Reuse

System Component	Capital/Initial Cost	Annual O&M Cost	Present Value of O&M Cost for 30 Years	30-Year Life-cycle Cost
Direct Expenses				
Desalination	$44,810,000	$7,120,000	$98,010,000	$142,820,000
Transmission System	12,540,000	900,000	12,390,000	24,930,000
Distribution System Modifications	3,250,000	50,000	690,000	3,940,000
Brine Disposal	2,310,000	280,000	3,850,000	6,160,000
Monitoring and Compliance	690,000	60,000	830,000	1,520,000
Subtotal: Direct Expenses	*$63,600,000*	*$8,410,000*	*$115,770,000*	*$179,370,000*
Revenue and Avoided Expenses				
Revenue: Water Sales*		($4,020,000)	($55,390,000)	($55,390,000)
Avoided Cost: UV Disinfection		(500,000)	(6,880,000)	(6,880,000)
Total	$63,600,000	$3,890,000	$53,500,000	$117,100,000

* Of the 49,000 m^3/day (13 mgd) of WWTP effluent, it is assumed that 36,800 m^3/day (9.7 mgd) is desalinated for nonpotable reuse and 12,200 m^3/day (3.3 mgd) is discharged as brine.

Table 2.7-2
Energy Requirements for Effluent Reuse

System Component	Desalination	Transmission	Total
Annual Electricity Requirement (kWh)	39,200,000	2,050,000	41,250,000
Unit Electrical Requirement (kWh/m^3 [kWh/million gal] produced)	2.91 (11,000)	0.15 (600)	3.06 (11,600)
Annual Oil Requirement (barrels)	65,300	3,400	68,700

2.7.6.2 Unit Costs for Effluent Reuse

Water is often sold based on a unit cost. The unit cost is calculated as the total annualized cost divided by the number of units produced in a year. The total annualized cost includes recurring costs such as O&M plus annualized capital costs. Capital costs are annualized at a rate of 6 percent over a period of 30 years for the purpose of this analysis. The cost to treat and deliver 1 m^3 (265 gal) of effluent for local reuse is estimated at $0.96. With nonpotable irrigation water available from the BWS at a cost of $0.30 per m^3 ($1,135/million gal), irrigation reuse of effluent from the WWTP at Fort Kamehameha is not economically viable at the present time.[65] Table 2.7-3 summarizes the calculation of the unit cost of reclaimed water.

[65]City and County of Honolulu, Board of Water Supply (July 1996) *Schedule of Rates and Charges.*

Table 2.7-3
Unit Cost of Reclaimed Water*

System Component	Initial/ Capital Cost	Annualized Initial/ Capital Cost	Annual O&M Cost	Total Annual Cost	Unit Cost ($/m^3)**	Unit Cost ($/million gal)
Direct Expenses						
Desalination	$44,810,000	$3,260,000	$7,120,000	$10,380,000	$0.77	$2,926
Transmission	12,540,000	910,000	900,000	1,810,000	0.13	510
Distribution	3,250,000	240,000	50,000	290,000	0.02	82
Brine Disposal	2,310,000	170,000	280,000	450,000	0.03	127
Monitoring & Compliance	690,000	50,000	60,000	110,000	0.01	31
Subtotal: Direct Expenses	*$63,600,000*	*$4,630,000*	*$8,410,000*	*$13,040,000*	*$0.96*	*$3,675*
Revenue and Avoided Expenses						
Revenue: Water Sales			($4,020,000)	($4,020,000)	($0.30)	($1,133)
Avoided Cost: UV Disinfection			(500,000)	(500,000)	($0.04)	($141)
Total:	$63,600,000	$4,630,000	$3,890,000	$8,520,000	$0.63	$2,402

* Arithmetic inconsistences are due to rounding.
** Assumes 36,800 m^3/day (9.7 mgd) of reclaimed water for 365 days.

2.7.7 Feasibility of Effluent Reuse

This alternative is conceptually desirable but presently not feasible because its cost far exceeds that of other feasible disposal alternatives if the water produced is sold at market prices. There would be no purchasers for the effluent if priced at its cost of production. This alternative is not further evaluated.

2.8 Screening of Alternatives

A preliminary evaluation, or screening, of the proposed action and alternatives identified and discussed in the previous sections was performed to determine their capacity to satisfy the purpose of and need for the project and possible environmental effects based on an initial review. Those alternatives that "passed" the screening, (i.e., met the purpose and needs, were practical for procurement as designed to meet these needs, and did not have unacceptable potential environmental effects) are considered feasible alternatives and are carried forward for more detailed environmental analysis in Chapter 4. Those that did not "pass" the screening are eliminated from further consideration.

2.8.1 Screening Process

The proposed action and alternatives were first evaluated based on whether or not the disposal system met the purpose, which is to reduce pollutant loadings from the discharge of wastewater effluent into the WQLS of Pearl Harbor Estuary. The evaluation then focused on the ability of each alternative to satisfy the needs of the project, which are to provide an effluent disposal system that meets all environmental and regulatory constraints and is similar in capacity and operational reliability to the existing outfall.

Costs of each alternative were then considered separately in the screening process. Lastly, feasibility of implementation was considered, including construction, operation, and maintenance of the disposal system.

2.8.2 Results of Screening

The results of the screening process are compiled in Table 2.8-1 and summarized as follows:

- Replacement Outfall (Proposed Action). The proposed action meets the purpose and satisfies the needs of the project. It has a reasonable cost and can be implemented without major uncertainties or unmanageable problems. Construction of the replacement outfall will have temporary impacts on water quality and living coral, but the impacts would not be significant. Based on these findings, this alternative is feasible and is carried forward for detailed environmental impacts analysis in Chapter 4.

- Underground Injection. Underground injection of effluent would eliminate the direct discharge of wastewater effluent into the Pearl Harbor Estuary, thus reducing pollutant loadings into the estuary from this source. The system could also be designed to satisfy all environmental and regulatory constraints and dispose of the same volume of wastewater as the existing outfall. However, uncertainties regarding the operational reliability of this alternative exist since the effluent may migrate to nearby surface waters, and because there is a tendency for sediment and bacterial growth to accumulate in and clog the wells. The cost of this alternative ($34.9 million) is comparable. It is unknown whether this alternative would affect surface waters and/or archaeological resources. Although uncertainties exist, they are manageable and do not make this alternative infeasible. Thus, the underground injection alternative is analyzed in more detail in Chapter 4.

- No Action. The no-action alternative does not meet the purpose of the project and will not satisfy anticipated future regulatory requirements. Because this alternative proposes a status quo, initial costs are low and there is no present problem with implementation. However, future risks and associated costs of exceeding discharge limitations may be high, but cannot be quantified. In accordance with 40 CFR 1502.14(d) and 1502.16(d), the environmental impacts of this alternative will be further analyzed in Chapter 4 since it represents the present situation.

- Treatment Plant Upgrade. The treatment plant upgrade would not remove the discharge from the Pearl Harbor Estuary, but it would meet the purpose of the project by reducing specific pollutant concentrations in the effluent. This alternative would also satisfy the needs of the project because it would treat the same amount of wastewater as the existing plant, would be operationally reliable, and would meet environmental and regulatory constraints. These needs would be accomplished at a high cost (at least $69.7 million). Because of the land constraints in the vicinity of the WWTP at Fort Kamehameha, it would be difficult to implement this alternative. The construction required to upgrade the treatment plant also has the potential to impact wetlands, cultural resources, and human burials that exist in the area. Because the treatment plant upgrade alternative has numerous implementation risks and constraints, including the potential for more stringent regulatory requirements, as well as an unreasonably high cost, it was eliminated from further analysis.

Table 2.8-1
Screening of Proposed Action and Alternatives

Alternative	Meets Purpose	Satisfies Needs (other than cost)	Cost	Implementation Feasibility	Preliminary Environmental Review	Retain or Reject
Replacement Outfall (Proposed Action)	Yes	Yes	Moderate ($21.6 million)	Feasible	• Construction impacts on water quality and coral	Retain
Underground Injection	Yes	Unknown; uncertainty regarding injected effluent migration to nearby surface waters	Moderate ($34.9 million)	Marginally feasible due to uncertainty regarding well reliability	• Unknown effect of injection on aquifer and surface waters • Uncertainty due to unknown geologic conditions • Potential impacts on archaeological resources and human burials	Retain
No Action	No	No; will not meet anticipated environmental constraints	Low ($1.5 million)	Infeasible due to anticipated permit non-compliance	• Continued discharge to Pearl Harbor Estuary	Retain
Treatment Plant Upgrade	Yes	Yes	High (at least $69.7 million)	Infeasible due to land constraints, high costs, and potentially more stringent regulatory requirements	• Potential impact on wetlands, cultural resources, and human burials	Reject
Infiltration and Evaporation	Yes	Yes	Infeasible (at least $160 million)	Infeasible due to large land requirements	• Impact a large land area • Potential impacts on archaeological resources and human burials	Reject
Effluent Reuse	Yes	Unknown; uncertainty regarding injected brine migration to nearby surface waters	Infeasible ($117.1 million)	Infeasible due to high cost of production	• Potential impacts of brine injection on water quality • Potential impacts on archaeological resources and human burials • Positive impact as a source of water	Reject

- Infiltration and Evaporation. The infiltration/evaporation alternative satisfies the purpose and needs for the project, but its extensive land requirement and cost (at least $160 million) are considered unreasonable. The land required (at least 105 ha [260 ac]) for the infiltration/evaporation of wastewater effluent makes this alternative impractical to implement. In addition, since a large land area would be influenced by this alternative, it is likely that there would be numerous environmental impacts, including impacts to archaeological resources. Based on this information, the infiltration/evaporation alternative was eliminated from further analysis.

- Effluent Reuse. Although the effluent reuse alternative meets the purpose of the project, it does not satisfy the specified needs. The effluent reuse system can be designed to meet all regulatory and environmental constraints and have similar capacity to the existing outfall, but it is unknown whether this alternative is as reliable operationally as the existing outfall because the demand for irrigation water is variable, and because it involves the underground injection of brine, which may migrate to nearby surface waters and cause degradation of water quality. The cost of the system ($117.1 million) and energy requirements (41 million kilowatt hours per year) also makes it infeasible to implement this alternative. Potential impacts of effluent reuse on water quality and construction impacts on archaeological resources were identified as environmental constraints, which could further increase the costs of effluent reuse.

  Although the reuse of effluent from the WWTP at Fort Kamehameha could help meet Oahu's long-term water needs, for effluent reclamation to be viable, it must be:

  - *Of adequate quantity*. Available in adequate quantities at least 95 percent of the time.
  - *Of adequate quality*. Source must consistently meet DOH guidelines and maximum allowable chloride concentration requirements for irrigation.
  - *Economical*. Sufficient demand must exist for nonpotable water at the offered price (comparable BWS sources of nonpotable water available for use costs $0.30/m^3 [$1.14/1,000 gal]).

  The reuse alternative is currently uneconomical because the effluent would need to be desalinated to meet minimum water quality requirements, which drives the price far above that of alternative sources. Hence, it is not now feasible as a source of irrigation water. Should it be determined in the future that large-scale desalination of sea water or groundwater is needed on Oahu, wastewater effluent should be considered as a potential source of relatively low chloride feed water with substantially lower desalination energy demands than sea water. However, because of the present uncertainties regarding brine disposal, high cost, and potential archaeological impacts, the effluent reuse alternative was eliminated from further analysis.

2.9 Summary of Alternatives Considered for Further Analysis

From the analysis in Section 2.8, it was determined that the alternatives, which will be further analyzed in detail in Chapter 4, are:

- Outfall Replacement (Proposed Action),
- Underground Injection, and
- No Action.

The other alternatives did not pass the first tier of screening performed in Section 2.8 and no action must be analyzed in accordance with 40 CFR 1502.14(d) and 1502.16(d).

Table 2.9-1 provides a summary of the alternatives considered for further analysis, including whether each of the alternatives meets the project's purpose and need, regulatory constraints, construction methods, O&M features, and costs. Table 2.9-2 presents a matrix of these alternatives, with issues and potential environmental impacts associated with each alternative.

The matrix compares impacts of alternatives, using a nonnumerical system of pluses and minuses based on the significance factors for each issue:

0	No impact
-	Nonsignificant **negative** impact
- -	Significant **negative** impact
+	Nonsignificant **positive** impact
+ +	Significant **positive** impact

The matrix is not designed to give a numerical evaluation of each alternative. Rather, it compares the impacts of each alternative on a particular issue or area of concern and provides a qualitative basis for considering the relative environmental effects of all alternatives.

2.10 Summary of the Proposed Action

Based upon the analysis of environmental impacts presented in Chapter 4 and summarized in Table 2.9-2, and the regulatory constraints and life-cycle costs that were presented in this chapter, the proposed action is the preferred alternative. The proposed replacement outfall will terminate in a 200-m (656-ft)-long diffuser at the 46-m (150-ft) depth in Class A Open Coastal Waters. Most potential impacts will be mitigated by compliance with existing regulatory requirements. Additional mitigation of potential construction impacts is provided by selection of outfall alignment and construction methodology and by implementation of best management practices during construction.

Table 2.9-1
Summary of Proposed Action and Alternatives Considered for Further Analysis

Issue	Replacement Outfall (Proposed Action)	Underground Injection	No-Action Alternative
Satisfy Purpose and Need	Yes	Yes	No
RECEIVING ENVIRONMENT AND REGULATIONS			
Receiving Environment	Coastal Waters (Mamala Bay)	Brackish Groundwater (Limestone Caprock Aquifer)	Inland Waters (Pearl Harbor Entrance Channel)
Regulatory Requirements	Clean Water Act: Section 401/HAR 11-54: Construction activities. Section 402/HAR 11-55: Effluent quality requirements for WWTP operation. Best management practices plan for construction. Section 404: Discharge associated with trenching and backfilling. HAR 11-23, Underground Injection Control: Disposal of dewatering effluent seaward of UIC line. U.S. Coast Guard/FAA: Construction impacts on navigation and aircraft. Rivers and Harbors Act Section 10: Work or structures that may affect navigable waters. Marine Protection Research and Sanctuaries Act of 1972 Section 103: Transportation and disposal of dredged material at the South Oahu ODMDS. Other Regulations: Water Resources and Development Act. Endangered Species Act. Magnuson-Stevens Act/Sustainable Fisheries Act. Marine Mammal Protection Act. Coral Reef Protection. Protection of Wetlands. Coastal Zone Management. National Historic Preservation Act. Native American Graves Protection and Repatriation Act. Responsibilities of Federal Agencies to Protect Migratory Birds. Environmental Justice for Minority and Low-Income Populations.	Clean Water Act: Section 404: Discharge associated with well construction in jurisdictional wetlands. HAR 11-23, Underground Injection Control: Disposal only seaward of UIC line. Well design. Record-keeping and reporting. FAA: Notification and marking of drill rigs during well construction. Other Regulations: Endangered Species Act. Magnuson-Stevens Act/Sustainable Fisheries Act. Protection of Wetlands. Floodplain Management. National Historic Preservation Act. Native American Graves Protection and Repatriation Act. Coastal Zone Management. Responsibilities of Federal Agencies to Protect Migratory Birds. Environmental Justice for Minority and Low-Income Populations.	Clean Water Act: Section 402/HAR 11-55 (NPDES): Effluent quality requirements for WWTP discharge. Increasingly stringent permit requirements are anticipated to result in non-compliance. Rivers and Harbors Act Section 10: Work or structures that may affect navigable waters. Other Regulations: Coral Reef Protection. Environmental Justice for Minority and Low-Income Populations.

Table 2.9-1 *(continued)*

Issue	Replacement Outfall (Proposed Action)	Underground Injection	No-Action Alternative
CONSTRUCTION			
System Components to be Constructed	New 107-cm (42-inch)-diameter marine outfall with 200-m (656-ft)-long diffuser at 46-m (150-ft) depth.	• Injection wells • Pump station and transmission line • Return line for well backflush water • Chlorination facility • Equalization basin	None
Construction Methodology	• Open trenching. Barge-mounted crane for depths greater than 1 m (3 ft) • Impact excavation for solid rock • Microtunneling	• Pipelines: trench or microtunnel • Wells: rotary, cable tool • Equalization basin: excavation and dewatering	Not Applicable
Construction Duration	24 months	18 months	Not Applicable
OPERATIONS AND MAINTENANCE			
Long-term Requirements	Outfall may require repair. Repair likely to be accomplished using divers.	Booster pumps likely to require overhaul within 10 years. When injection well capacity degrades, new wells may need to be drilled.	Outfall may require repair, which would likely be accomplished using divers. Will not meet long-term regulatory requirements (see above).
Reliability	Excellent. No significant operational problems anticipated. Existing outfall will provide backup.	Fair to Poor. Wells prone to clogging. Injection capacity will degrade over time.	Good. No significant operational problems anticipated except regulatory (see above).
COSTS			
30-Year Life-cycle Cost	$21.6 million	$34.9 million	$1.5 million
Capital Cost	$20.3 million	$13.4 million	$0
O&M Cost	$0.10 million/year	$1.56 million/year	$0.11 million/year
Energy Use	<10,000 kWh/year	560,000 kWh/year	<10,000 kWh/year

Table 2.9-2
Matrix of Potential Impacts for Evaluated Alternatives

Potential Issue/Impact	Alternatives		
	Replacement Outfall (Proposed Action)	Underground Injection	No Action
AQUATIC ENVIRONMENT			
Turbidity plume impacts on marine biota due to construction	-	0	0
Sea floor excavation impacts on marine biota	-	0	0
Water quality impact of wastewater discharge in Class A Open Coastal Waters within the ZOM	-	0	0
Water quality impact of wastewater discharge in Class 2 Inland Waters	+	Not known	-
Impact of wastewater disposal outside the ZOM	0	Not known	0
Cumulative impacts on Mamala Bay water quality	0	Not known	0
SOCIOECONOMIC			
Recreational and personal consumptive activities in Mamala Bay	-	0	0
Recreational and personal consumptive activities in Pearl Harbor Estuary	+	0	-
Commercial activities in Mamala Bay	-	0	0
Commercial activities in Pearl Harbor Estuary	+	0	-
PROTECTED SPECIES			
Impacts on terrestrial biota	0	-	0
Impacts on aquatic biota and water birds	-	0	0
CULTURAL RESOURCES			
Archaeological artifacts, human burials	0	- -	0
Historic period resources	0	-	0
PUBLIC HEALTH AND SAFETY			
Hazards from ordnance items	-	0	0
Potential health impact to recreational users	0	Not known	-
NAVIGATION			
Impacts to ship passage in Pearl Harbor Entrance Channel	-	0	0
Impacts to outfall from anchor entanglement	-	0	-
WATER AS A RESOURCE			
Impact on existing water sources	0	0	0
Impact on future water sources	0	0	0

CHAPTER THREE

REGIONAL ENVIRONMENTAL SETTING

CHAPTER THREE
REGIONAL ENVIRONMENTAL SETTING

3.1 Introduction

The purpose of this chapter is to provide information about the regional environmental setting of areas affected by the proposed action, underground injection, and no-action alternatives presented in Chapter 2. These affected areas are referred to as "regions of influence." Chapter 4 provides a more detailed discussion of environmental conditions relevant to the significant issues identified, along with a detailed analysis of the impacts of the proposed action, underground injection, and no-action alternatives.

3.2 Regions of Influence

Regions of influence are the geographic boundaries within which the proposed action or the alternatives being considered may exert some discernible effect. These regions of influence vary, depending upon the resource or effect being evaluated (e.g., water quality has a different region of influence than air quality; the socioeconomic region of influence differs from that of navigation). In general, the regions of influence can be divided into two categories: aquatic and land environments.

3.2.1 Aquatic Environment

The aquatic environment includes the Pearl Harbor Estuary along with its benthic ecosystem and the immediately adjacent marine waters of Mamala Bay. Each segment of the aquatic environment is classified and regulated, as discussed in Section 3.4.

3.2.1.1 Pearl Harbor Estuary

Pearl Harbor is a natural estuary on the southern shore of Oahu. Three lochs—West Loch, Middle Loch, and East Loch—form the harbor. The Pearl Harbor Naval Complex is established on much of the Pearl Harbor shoreline and controls access to the harbor under Executive Order 8143, which established the Pearl Harbor Defensive Sea Area (see Figure 1.6-1). The benthic ecosystem of Pearl Harbor includes nearshore reef flats, which are shallow platforms of reef rock, rubble, and sand extending from the shoreline, in addition to dredged and undredged sand and silt bottoms. The Pearl Harbor Estuary is in the region of influence for water quality, biota, and navigational concerns.

3.2.1.2 Mamala Bay

Mamala Bay includes all ocean areas from Diamond Head to Barbers Point, Oahu (see Figure 1.6-1). Several regulated and unregulated point sources of pollution discharge into Mamala Bay. In addition to the discharges from the three wastewater treatment plant (WWTP) outfalls previously noted (from the Sand Island WWTP [SIWWTP], the WWTP at Fort Kamehameha, and the Honouliuli WWTP [HWWTP]), other discharge sources to Mamala Bay include the Ala Wai Canal (into which Manoa Stream discharges); Nuuanu, Kapalama, Kalihi, and Moanalua streams; other smaller streams and drainage channels; and Pearl Harbor. Mamala Bay is in the region of influence for water quality and navigational concerns.

3.2.2 Land Environment

In general, the potentially affected land environment consists of areas of Oahu immediately adjacent to the Pearl Harbor Estuary and Mamala Bay in the vicinity of the WWTP at Fort Kamehameha (where construction activities would occur for the outfall replacement or for the underground injection alternative). These areas include Hickam Air Force Base (AFB), Honolulu International Airport, and a portion of the Naval reservation land north of Hickam AFB. The existing land uses of these areas are presented in Section 3.7.

3.3 Physiography

This section presents a general overview of the physical environment, or physiography, of the project site, including the climate, topography, geology, hydrology, air quality, and physical oceanography.

3.3.1 Climate

The Hawaiian Islands are located at the edge of the Tropics Zone, where the climate is generally mild throughout the year. During the summer months, average temperatures range from approximately 32°C (90°F) during the day to 23°C (73°F) at night. Average temperatures during the winter and early spring months range from daytime highs of about 26°C (79°F) to nighttime lows of 15°C (59°F). Average relative humidity at Pearl Harbor varies between 58 percent in the afternoon to over 80 percent at night.

The frequency of the trade winds varies greatly in the Hawaiian Islands. The islands may experience periods of no wind followed by days of constant trade winds. In general, trade winds are more persistent in the summer months than in winter months. Northeasterly trade winds prevail over Oahu throughout most of the year and comprise "offshore" wind conditions at the project site. Moderate to strong southerly winds associated with "Kona" frontal passages occur periodically during the winter and comprise "onshore" conditions at the project site. On the open seas, trade winds average under 24 kilometers per hour (15 miles per hour) and are slightly stronger in summer than in winter.

3.3.2 Topography

The WWTP at Fort Kamehameha is located on the eastern side of the Pearl Harbor Entrance Channel, fronting the shoreline on the flat coastal plain known as the Pearl Harbor Plain. This coastal plain, which consists of coralline sand, rises no more than 1 to 1.2 meters (m) (3 to 4 feet [ft]) above sea level.

3.3.3 Geology and Soils

Underlying southern Oahu is a caprock composed of layers of marine calcareous deposits, such as coral limestone and land-derived sediments or clays. This caprock system extends for several miles and reaches to a depth of about 330 m (1,080 ft) below sea level at the WWTP. The caprock retards the seaward movement of groundwater because of its decreased permeability.[1] It also confines the Pearl Harbor basal aquifer system, which has an estimated groundwater flux of

[1]Gordon A. Macdonald, Agatin T. Abbott, and Frank L. Peterson (1986) *Volcanoes in the Sea: The Geology of Hawaii.*

840,000 cubic meters per day (m^3/day) (222 million gallons per day [mgd]) and currently supplies over half of Oahu's total water needs.[2,3]

Pearl Harbor, which consists of three lochs, is essentially a series of drowned river valleys. The roundness of the lochs suggests that these valleys have widened over time because the sediments are easily eroded. In contrast, the valley of the main channel at the harbor entrance remains narrow because of the sturdy coral reef.[4] Over time, sediments from the surrounding land areas washed into the harbor, accumulating and forming layers of mud, silt, and sand. As the harbor depth increased, coral reefs were covered by land-derived silts and sands.

Marine deposits in the area of the Pearl Harbor Entrance Channel are expected to consist mainly of hard cemented coral layers or ledges and uncemented to partially cemented coralline detritus, such as coralline gravels, sands, and cobble-to-boulder-sized coral chunks. Due to sea level fluctuations during the last million years, fine estuarine sediments, such as silts and clays, were deposited during higher sea stands. These sediments may have soft to very stiff consistencies.

According to underwater reconnaissance and marine seismic refraction surveys, the sea floor outside of the Pearl Harbor Entrance Channel, at depths below about 25 m (82 ft), consists of loose sand deposits estimated to be approximately 3 to 9 m (10 to 30 ft) thick.[5] Very loose sand deposits may become unstable under disturbing stresses induced by storm surges or earthquake conditions.

The soils in the Fort Kamehameha area are of the Lualualei-Fill land-Ewa association. The naturally occurring soils are deep, nearly level to moderately sloping, well-drained soils which have a fine-textured or moderately fine-textured subsoil or underlying material; they are interspersed by areas of fill land.[6] Four different soils of this association cover the Fort Kamehameha area: Mamala stony silty clay loam, Jaucas sand, coral/cemented calcareous sand, and fill land. Mamala stony silty clay loam has a moderate permeability, runoff is very slow to moderate, and it often contains stones or coral rock fragments that hinder cultivation. Jaucas sand has a high permeability, runoff is very slow to slow, and the soil's workability is slightly difficult because it is loose and lacks stability. A coral outcrop, which consists of coral or cemented calcareous sand with a thin layer of friable, red soil material (similar to that of the Mamala series) in the cracks and crevices, surrounds Bishop Point. Much of the Fort Kamehameha area is land filled with solid waste, general materials, and dredged material from the ocean and other nearby areas.[7]

A preliminary geotechnical evaluation of the proposed outfall alignment, consisting of one onshore boring and three offshore borings, was conducted in March 1997. The borings ranged in depth from 7 to 37 m (23 to 121 ft) beneath the surface (onshore boring) or sea level (offshore borings). The onshore boring, located near the shoreline of the WWTP, encountered silty sands and gravelly reef detritus to a depth of approximately 14 m (46 ft). This was underlain by estuarine clays and silts, silty sands, and volcanic tuff, the latter occurring at a depth of approximately 19 m (62 ft). The offshore borings, located along the eastern side of the Pearl Harbor Entrance Channel,

[2]George A.L. Yuen & Assoc., Inc. (May 1988) *Review and Re-evaluation of Groundwater Conditions in the Pearl Harbor Groundwater Control Area, Oahu, Hawaii.* Prepared for the State of Hawaii, Commission on Water Resource Management. Hawaii Department of Land and Natural Resources Report R-78.

[3]Wilson Okamoto & Associates, Inc. (May 1994) *Oahu Water Management Plan, Initial Revision of Technical Reference Document.* Prepared for City and County of Honolulu, Department of General Planning.

[4]Kanalei Shun and Allan Shilz (March 1991) *Surface and Sub-surface Archaeological Survey of Construction Areas at Wastewater Treatment Plant at Fort Kamehameha, Oahu, Hawaii.* Prepared for the Department of the Navy, Pacific Division, Naval Facilities Engineering Command.

[5]SSFM, Inc. (October 1996) *Oceanographic Study for Outfall Extension for Wastewater Treatment Plant at Fort Kamehameha.* Prepared for the U.S. Navy, Pacific Division, Naval Facilities Engineering Command.

[6]U.S. Department of Agriculture, Soil Conservation Service, in cooperation with the University Hawaii Agricultural Experiment Station (August 1972) *Soil Survey of Kauai, Oahu, Maui, Moloka'i, and Lanai, State of Hawaii.*

[7]Kanalei Shun and Allan Shilz (March 1991).

encountered silty sand, silt, and gravelly reef detritus. The reef detritus included cobble-sized coral chunks and locally cemented zones. The geotechnical report is included in Appendix IV.

3.3.4 Hydrology and Drainage

Oahu's potable water supply depends greatly upon the hydrologic cycle that starts with the evaporation of water from the ocean, followed by the condensation of that water to produce rain (primarily in the mountains), and then capture of that rain by the ground and infiltration to groundwater aquifers. The groundwater aquifers function as huge fresh water storage reservoirs beneath the island. Groundwater that is not withdrawn for human and agricultural use flows through the aquifer by gravity and eventually discharges to streams and to the ocean. Rainwater that does not percolate through the soil to become groundwater flows overland and is carried by streams and drainage channels to the ocean. Surface water discharging into the ocean through Pearl Harbor Estuary carries sediment and other contaminants from the watershed. Some of these contaminants reach the ocean while others remain in the estuary.

3.3.4.1 Ground and Surface Waters

The potentially affected areas are located over a coastal portion of the Pearl Harbor Aquifer extending from Red Hill to the Waianae Mountains and north from Pearl Harbor to Wahiawa. The Pearl Harbor Aquifer is a basal aquifer that consists of fresh water floating on heavier sea water within basaltic strata. The water table ranges from 4.9 to 7.6 m (16 to 25 ft) above sea level (depending on the distance inland, the prevailing rainfall, and groundwater withdrawal). Much of Oahu's potable water comes from the Pearl Harbor Aquifer, making it a valuable source of groundwater. The project site is located on the saltwater fringe of this aquifer (the edge of the aquifer where the fresh and salt water mix).

The Pearl Harbor Aquifer has a broad, thick caprock, a relatively impermeable layering of coral limestone, and land-derived sediments. However, there are numerous areas where the basaltic rock is exposed at the ground surface. In most of these areas, the basaltic rock is sufficiently weathered to retard permeability; in other areas, such as those adjacent to stream channels, the basaltic rock is highly permeable. Several large springs, known as the Pearl Harbor Springs, exist at these locations. The largest measurable groundwater flow, estimated at between 78,000 to 852,000 m^3/day (21 to 225 mgd), occurs at the springs.[8] Groundwater also discharges along the shore and in stream channels below seawater or stream water level.

The eight streams that presently discharge into Pearl Harbor are Honouliuli, Waikele, Waiawa, Waiau, Waimalu, Kalauao, Aiea, and Halawa. The Honouliuli and Aiea streams are intermittent while the others are perennial. The perennial streams originate in the Koolau Range and constantly bring fresh water to the Pearl Harbor Estuary. All of the streams drain forested and agricultural lands and pass through urban areas prior to discharging into the estuary.

There are three canals within Hickam AFB. The Transportation Canal forms the northern border of the WWTP at Fort Kamehameha and discharges into the Pearl Harbor Entrance Channel. The Kumumau Canal drains an area north of Hickam Harbor and discharges into Hickam Harbor. The Manuwai Canal passes through the eastern portion of the 18-hole Hickam Mamala Bay Golf Course on Hickam AFB and discharges to the portion of Mamala Bay inland of the Reef Runway.

[8] Wilson Okamoto & Associates, Inc. (March 1990) *Oahu Water Management Plan*. Prepared for the Department of General Planning.

3.3.4.2 Drainage[9]

Drainage in the vicinity of the WWTP is provided primarily by percolation and several grated inlets. The existing grade of the facility is relatively flat, with a majority of its ground backfilled with gravel material which provides extensive percolation. There are four grated inlets located within the boundaries of the WWTP. Storm water collected in these inlets is pumped into the plant and processed. Runoff at the WWTP occurs in sheet flow. The sheet flow travels to the low points throughout the facility and eventually percolates through the ground and/or evaporates into the atmosphere. During periods of heavy rains, excessive sheet flows can also discharge into the Transportation Channel along the northern edge of the facility and into Pearl Harbor from the western half of the facility.

3.3.5 Air Quality

Favorable meteorological conditions throughout the islands help to disperse air pollutants, so the State of Hawaii is in compliance with the State and National Ambient Air Quality Standards (SAAQS and NAAQS) established for criteria pollutants.[10] Therefore, the project area is in an air quality attainment region and in conformance with SAAQS and NAAQS.

In terms of the pollutants regulated by the Department of Health (DOH), air quality in the vicinity of the WWTP is generally good. The primary air quality concern associated with a WWTP is odor, particularly from hydrogen sulfide gas released during treatment. Odors have the potential to infringe on neighboring Hickam AFB residential areas along the shoreline southeast of the WWTP.

3.3.6 Physical Oceanography

The shoreline and waters in the vicinity of the WWTP at Fort Kamehameha are subject to both ocean and estuarine conditions. Therefore, the currents, mixing, and water quality in the area are influenced by both ocean and estuarine processes.

The open coastal waters in the vicinity of Pearl Harbor are subject to three types of large waves: southern swells, Kona storm waves, and hurricane-generated waves. The ocean is connected to Pearl Harbor by a 4,570-m-long (15,000-ft-long) entrance channel. Pearl Harbor is protected from ocean waves and swells because wave propagation through the entrance channel is fully attenuated. Tidal currents are relatively mild; the strongest occur at the entrance to the harbor and in East Loch.

The waters of Pearl Harbor are influenced by a two-layer circulation system. The tides, winds, fresh-water inflow, and ship-induced turbulence all affect the water circulation. Layering occurs as a result of the large influx of fresh water into the harbor from streams. The boundary between the two layers occurs at about 1.5-m (5-ft) depth in the entrance channel but varies considerably depending on the season. The currents in the upper layer generally move seaward due to trade winds and the inflow of fresh water. The bottom seawater layer reverses with the tide, the reversal occurring approximately at the peak tidal amplitude.[11]

Sedimentation within Pearl Harbor is a natural occurrence. The Pearl Harbor drainage area is the largest on Oahu with eight streams carrying an estimated 318,000 kilograms (700,000 pounds)

[9]Written communication with Environmental Engineer, Navy Public Works Center (May 20, 1997).
[10]40 CFR Part 81.312.
[11]Belt Collins & Associates (August 1992) *Expansion of the Wastewater Treatment Plant at Fort Kamehameha Environmental Assessment*. Prepared for the Department of the Navy, Public Works Center.

per day of sediment into the harbor.[12] The presence of large amounts of sediment contributes to the relatively high turbidity in the estuary. West and Middle Lochs have the highest turbidity. The sediment, along with other contaminant sources such as runoff from urbanized areas, has a detrimental impact on Pearl Harbor water quality and can also impact nearby coastal waters.

3.4 Classification of the Aquatic Environment

The aquatic environments evaluated in this environmental impact statement include inland and marine waters and benthic environments. The water classifications and bottom types are shown in Figures 1.2-1 and 3.4-1, respectively, and are defined as follows:

- Inland waters are located inside the Pearl Harbor Entrance Channel and are known as the Pearl Harbor Estuary.

- Marine waters are outside the entrance channel. Marine waters bordered by the 183-m (600-ft or 100-fathom) depth contour and the shoreline are classified as Open Coastal Waters by the DOH. Marine waters outside the 183-m (600-ft or 100-fathom) depth contour are Open Oceanic Waters.

- The benthic ecosystem at the entrance to Pearl Harbor consists of reef flats and reef communities. The entrance channel is a dredged channel through the reef material. The bottom consists of sandstone and limestone rock with sand and gravel. It is covered with an accumulation of sediments of varying thicknesses. At the seaward end of the entrance channel, coralline rock and sand are encountered. Further in, the sand bottom gives way to silt and fine sediment.

The existing outfall in the Pearl Harbor Estuary was granted a zone of mixing (ZOM) as part of its National Pollutant Discharge Elimination System permit (No. HI 0110086). Part of the existing ZOM is in the Pearl Harbor Estuary and part is in the Open Coastal Waters immediately outside the harbor entrance (see Figure 1.2-1). It is fully contained within the boundaries of the Pearl Harbor Defensive Sea Area controlled by the Navy (see Figure 1.6-1).

3.4.1 Pearl Harbor Estuary

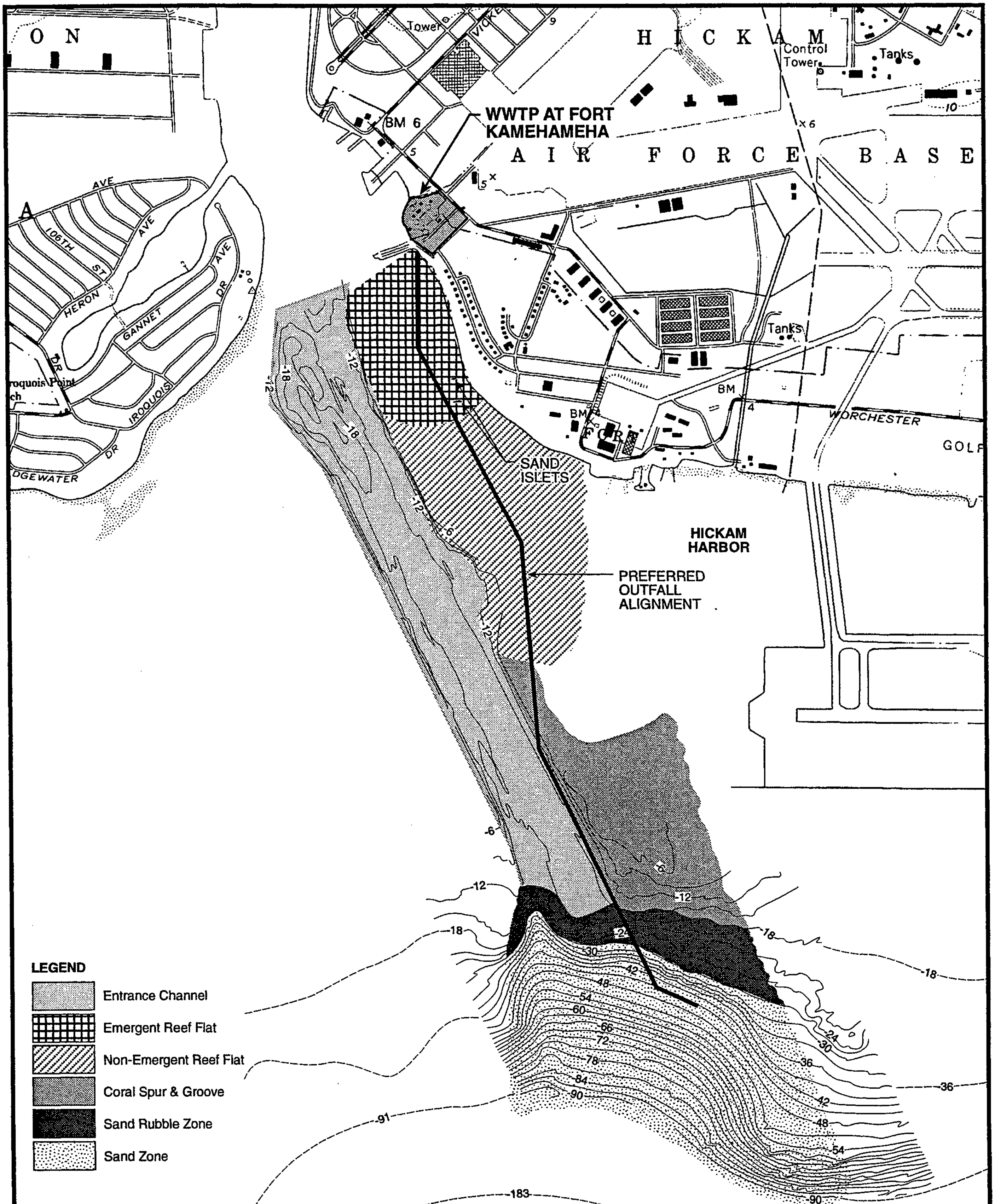
The waters of Pearl Harbor are considered an inland estuary and classified as Class 2 waters by the DOH. The objective of Class 2 waters is protection of their use for recreational purposes, the support and propagation of aquatic life, agricultural and industrial water supplies, shipping, and navigation.[13] Discharges into Class 2 waters must have undergone the best degree of treatment or control compatible with the criteria established for this class of water.

Pearl Harbor Estuary is also identified as one of the 14 Water Quality Limited Segments (WQLS) located in Hawaii.[14] WQLS were designated in response to Section 303(e) of the Federal Water Pollution Control Act of 1972. Without additional action to control nonpoint source pollution (NPSP), a WQLS cannot be expected to attain or maintain State water quality standards. Eight streams presently discharge into Pearl Harbor Estuary and may carry pollutants from upland

[12]Belt Collins & Associates (August 1992).

[13]State of Hawaii, Department of Health (April 2000) *Hawaii Administrative Rules, Title 11, Chapter 54, Water Quality Standards.*

[14]State of Hawaii, Department of Health (1988) *Hawaii's 305(b) Report on Water Quality for the Year Ending 1987.*



Source: SEA Engineering, Inc. (Dec. 1996). Fort Kamehameha Outfall Section Dredging Turbidity Investigations. Prepared for SSFM Engineers, Inc.

Note: Depth in meters (1m=3.28 ft)

Figure 3.4-1
BOTTOM TYPES ALONG PIPELINE ROUTE

EIS for Outfall Replacement, WWTP at Fort Kamehameha
March 2001

activities into the estuary.[15] No new wastewater discharges are permitted into the Pearl Harbor Estuary, and special water quality standards have been established by DOH for the estuary. Waters within the regulatory boundary of the existing ZOM are permitted to exceed water quality standards pursuant to Hawaii Administrative Rules Chapter 11-54 and conditions of the discharge permit. The ZOM was established to provide a limited area around the outfall for the initial dilution of wastewater discharges. The estuarine waters at the entrance to Pearl Harbor frequently experience elevated levels of turbidity, nutrients, fecal coliforms, and other contaminants, as a result of both point source pollution and NPSP of the estuary.

3.4.2 Marine Waters

The Open Coastal Waters outside the Pearl Harbor Entrance Channel are considered Class A marine waters by DOH. The objective of Class A waters is to protect their use for recreation, aesthetic enjoyment, or other uses compatible with recreation and the protection and propagation of fish, shellfish, and wildlife.[16] Discharges into Class A waters must receive the best degree of treatment or control compatible with the criteria established for this class.

3.4.3 Benthic Ecosystem

The benthic ecosystem encountered in Pearl Harbor includes reef flats, soft bottom communities that consist of burrowing organisms living in the silt and fine sediments, coral, and sandy bottoms. The benthic communities in the vicinity of the project comprise a Class II benthic ecosystem.[17] The objective of this class is to ensure the protection of aquatic resources, including propagation of fish, shellfish, and wildlife; and for recreational purposes, such as boating, fishing, and swimming, that are indirectly influenced by the benthic ecosystem. Any action which may permanently or completely modify, alter, consume, or degrade the benthic ecosystem (such as the placement of an outfall structure) is allowable upon approval from the DOH, after consideration of both the environmental impacts as well as the public interest.[18]

3.5 Biota

Many different life forms live, rest, or forage in the vicinity of the WWTP at Fort Kamehameha. Much of the vegetation is not native to Hawaii and was introduced to the area for landscaping purposes. Various bird species have been observed resting and foraging in the area. Marine life characteristic of the area near the existing outfall includes sea cucumbers, algae, coral, shrimps, and sessile invertebrates. The following sections provide an overview of the flora and fauna observed in the Fort Kamehameha area and in the vicinity of the existing outfall.

3.5.1 Terrestrial Flora

A botanical site inspection was performed in the vicinity of the WWTP and the Fort Kamehameha housing area on Hickam AFB in March 1992. No federally or state-listed threatened or endangered species were found in this area.

[15]State of Hawaii, Department of Health (November 1990) *Hawaii's Assessment of Nonpoint Source Pollution Water Quality Problems.*

[16]State of Hawaii, Department of Health (April 2000).

[17]State of Hawaii, Department of Health (April 2000).

[18]State of Hawaii, Department of Health (April 2000).

Prior to being filled, this area was a wetland. Most of the vegetation in the area is non-native species, introduced to the area for landscaping purposes. These include planted grasses, Norfolk Island pine, coconut trees, and hibiscus bushes. Also found in the vicinity of the WWTP are native species including kiawe trees (*Prosopis pallida*) with a scant shrub layer of sour bush (*Pluchea odorata*), Indian pluchea (*Pluchea indica*), and koa haole (*Leucaena leucocephala*). A thin covering of mixed grasses, some salt bush (*Atriplex semibaccata*), spiny amaranth (*Amaranthus spinosus*), akulikuli (*Sesuvium portulacastrum*), and false ragweed (*Flavera trinervia*) can be seen on the ground.[19] Jurisdictional wetlands[20] are located along the Hickam AFB shoreline and in the flat plain that comprises Fort Kamehameha, as shown in Figure 3.5-1. These areas are home to obligate wetland vegetation, such as red mangrove trees (*Rhizophora mangle*) and pickleweed (*Batis maritima*). Red mangrove trees and pickleweed also line the Transportation Canal north of the WWTP and the drainage channel east of the WWTP.

3.5.2 Terrestrial Fauna

A site-specific survey of areas associated with the outfall replacement project was conducted on two separate days in late 1996. The purpose of the survey was to observe migratory shorebirds, resident water birds, and seabirds at the Fort Kamehameha wetlands and offshore islets. The results of this survey were then compared to the results of surveys conducted in 1993-1995 of the same area. The 1996 report is included in Appendix V.

Four species of migratory birds were seen resting and foraging in the area: the Pacific golden plover (*Pluvialis fulva*), ruddy turnstone (*Arenaria interpres*), sanderling (*Calidris alba*), and wandering tattler (*Heteroscelus incanus*). The only native water bird observed during this survey was the black-crowned night heron (*Nycticorax nycticorax*), which was seen roosting in the mangrove trees fronting the *Batis* wetlands. The night heron, which usually forages along shorelines and in shallow wetlands, is not listed as a threatened or endangered species.

Past surveys revealed the presence of several other bird species in the area, such as the Hawaiian stilt (*Himantopus mexicanus knudseni*), a listed endangered species.[21] Therefore, it is assumed that the report refers to a Hawaiian stilt. In addition, two species of seabirds were observed foraging in the Pearl Harbor Entrance Channel and offshore: the brown booby (*Sula leucogaster*) and the common or brown noddy (*Anous stolidus*). Several exotic bird species were also identified. The most abundant species were the zebra dove (*Geopelia striata*), common myna (*Acridotheres tristis*), and red-vented bulbul (*Pycnonotus cafer*). The Indian mongoose (*Herpestes auropunctatus*) and cats were the only feral mammals observed in the area.[22]

3.5.3 Marine Life

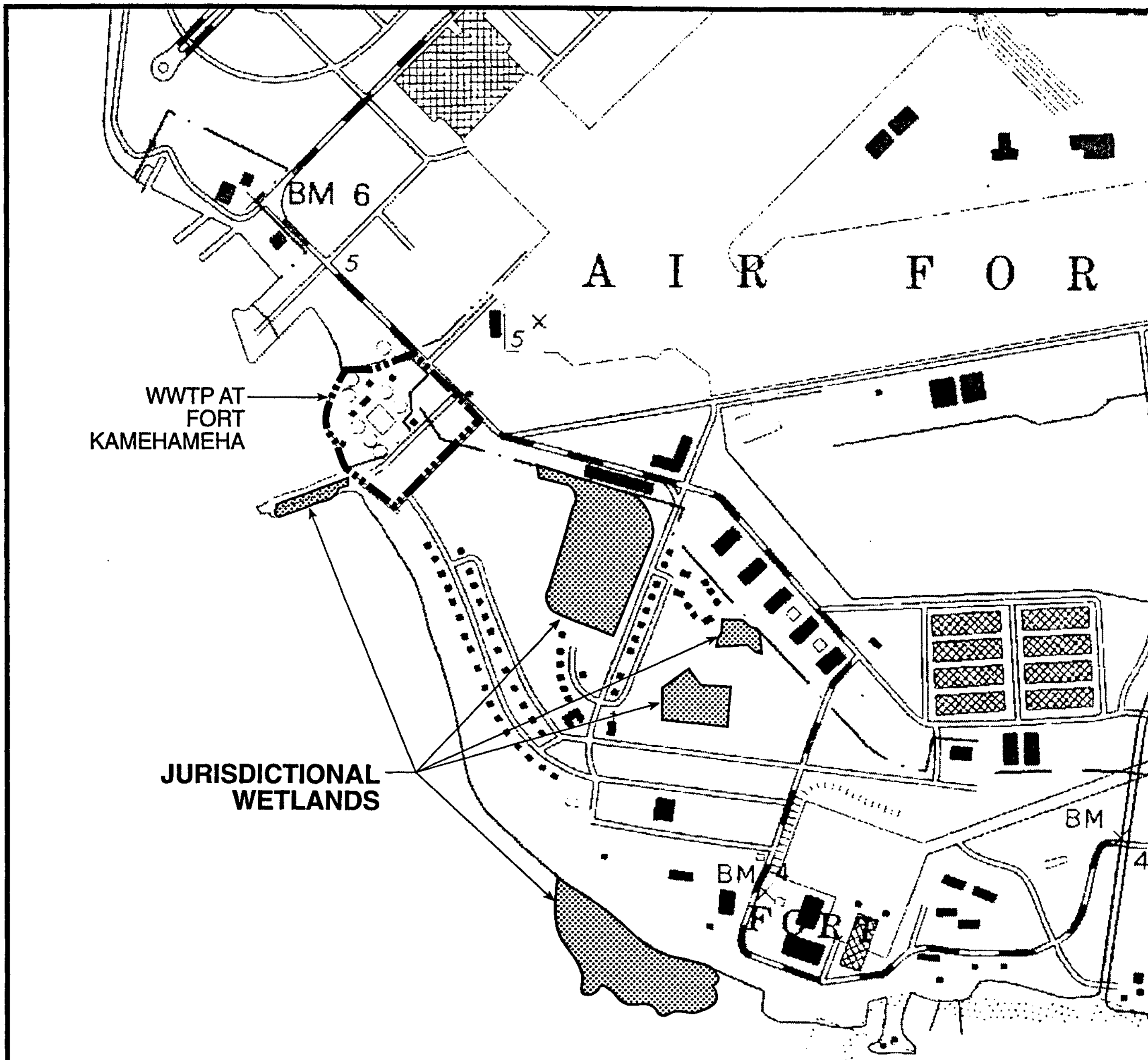
The inner Pearl Harbor benthic community is depicted by four zones: sand-rubble, algal-mud, channel wall, and channel floor mud-silt zones. Naturally occurring sedimentation greatly influences the constituents of the Pearl Harbor benthic community. Stony corals are not observed because they are sensitive to high-sediment loads. Predominant marine biota in the area include

[19] Belt Collins & Associates (August 1992).

[20] A jurisdictional wetland is a wetland that is subject to regulation by the USACE under Section 404 of the Clean Water Act. Jurisdictional wetlands must exhibit all three characteristics: hydrology, hydrophytes, and hydric soils. Areas that exhibit only one or two of the three characteristics do not qualify as USACE jurisdictional wetlands and are not regulated under the Section 404 program.

[21] The original survey report refers to the presence of the black-necked stilt in the area. The only known occurrence of the black-necked stilt in Hawaii is the Hawaiian stilt.

[22] Belt Collins & Associates (August 1992).



Source: USGS Pearl Harbor Hawaii Quadrangle 7.5 minute Topographic Series, 1983

Air Force Center for Environmental Excellence (June 1997) *Final Integrated Natural Resources Manangment Plan for Hickam AFB, Oahu; Bellows AFS, Oahu; Hickam POL Pipeline, Oahu; Kaala AFS, Oahu; Kaena Point STS, Oahu; Kokee AFS, Kauai; and Palehua Solar Observatory, Oahu (15th Air Base Wing Installations)*

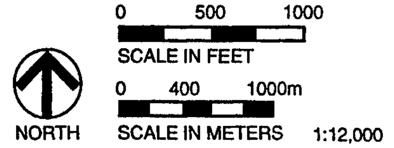


Figure 3.5-1
JURISDICTIONAL WETLANDS IN THE VICINITY OF THE WWTP AT FORT KAMEHAMEHA

the sea cucumber (*Ophiodesoma spectabilis*), which is common to areas where organic particulate input is high; benthic (bottom dwelling) algae; sponges; Sabellid (feather duster) worms; Serpulid worm tubes; and various benthic shrimps and crabs.

The existing outfall is located at the base of a channel wall dredged from a shallow coral reef flat. The primary inhabitants of the channel wall are a variety of sessile invertebrates, which include sponges, alcyonarians, polychaete and sipunculid worms, and bivalve mollusks. The diffuser pipe is located on a mud-silt bottom with little marine life living/growing on the mud surface. Burrow holes, which were probably formed by alpheid shrimp, are present throughout the mud surface.

The diffuser also provides a separate solid surface for settlement of sessile organisms. In 1992, diffuser ports were covered by sponges and alcyonarians, and several small green sea turtles (*Chelonia mydas*), with shell lengths less than 30 centimeters (cm) (12 inches), were observed in the vicinity of the diffuser pipe.[23] The green sea turtle is considered a threatened species and is under joint jurisdiction of U.S. Fish and Wildlife Service and National Marine Fisheries Service.

Green sea turtles were also observed during subsequent surveys. During a 1995/1996 biotic community survey, an inspection of the existing Fort Kamehameha outfall along the eastern channel wall adjacent to the reef flat revealed relatively large aggregations of green sea turtles. It appeared that these turtles use the space between the outfall pipe and the channel floor as a refuge area (Appendix VI). During a 1997 assessment of biological communities in the vicinity of the proposed outfall, green sea turtles were observed in two identified biotopes: the reef slope along the edge of the reef flat, and the biotope of limestone and corals west of the Reef Runway. These turtles appeared to be using areas with appropriate shelter characteristics for resting during the day (Appendix VII). A more detailed biotic community assessment along proposed outfall alignments in 1998 noted as many as 20 green sea turtles in a portion of the reef slope biotope along the Pearl Harbor Entrance Channel, where limestone blocks create a favorable resting habitat (Appendix VIII).

Endangered species, such as the Hawaiian monk seal (*Monachus schauinslandi*) and humpback whale (*Megaptera novaeangliae*), have rarely been sighted in the project area. Although the Hawaiian Islands Humpback Whale National Marine Sanctuary has been established in offshore areas north and south of Oahu, the closest sanctuary boundary to the project area extends from the shoreline at the Ala Wai Canal to the 183-m (600-ft or 100-fathom) isobath (not including the Ala Wai Small Boat Basin), approximately 8.9 kilometers (km) (5.6 mi) away.[24] The alternative alignments of the outfall pipe and diffuser pass through several benthic zones. Progressing seaward from the WWTP, beyond the shoreline there is a substantial reef flat, bounded by the dredged Pearl Harbor Entrance Channel on the west, Hickam Harbor on the east, and the reef slope and deeper waters of Mamala Bay on the south. The width of the flat between the two harbor channels varies from over 914 m (3,000 ft) inshore to about 457 m (1,500 ft) at the offshore slope. The alternative outfall alignments all cross through the occasionally emergent inshore reef flat, pass into deeper waters of the reef flat that do not emerge at lower tides, transition into the Pearl Harbor Entrance Channel, and follow the entrance channel into deeper water. The diffuser alternatives are located on sand and coral rubble slopes at depths of 21 m (70 ft) and 46 m (150 ft).

[23]Marine Research Consultants (June 22, 1992) *An Assessment of Water Quality in Pearl Harbor in the Vicinity of the Fort Kamehameha Wastewater Treatment Plant Phase II*. Prepared for Belt Collins & Associates.

[24]U.S. Department of Commerce, National Ocean Service, National Oceanic and Atmospheric Administration, Office of Ocean and Coastal Resource Management, Sanctuaries and Reserves Division and State of Hawaii, Department of Business Economic Development and Tourism (February 1997) *Hawaiian Islands Humpback Whale National Marine Sanctuary Final Environmental Impact Statement/Management Plan*.

Coral cover on the reef flat, reef slope and channel walls varies, being abundant in some locations and absent in others. A description of the coral cover and the benthic environment affected by the proposed outfall route is discussed in Section 4.4.3.3, Existing Marine Biota, as the alignment and construction method were selected largely to avoid significant impacts to living corals. The following is a general description of the biotic zones (see Figure 3.4-1).

The shallow reef flat area south of the treatment plant is sand-rubble out to approximately 914 m (3,000 ft) from the WWTP. Water depths average less than 0.6 m (2 ft) and introduced algae are dominant. Deeper waters of the reef flat, with depths averaging about 0.9 m (3 ft) at mean low water, extend southeastward an additional 1,219 m (4,000 ft). In this area, zones of sand, rubble, and hard substratum are mixed. Living corals occur at varying densities in this zone, including an area of "microatolls" at the inner portion of the nonemergent zone. Seaward, this area is followed by zones dominated by algae and areas relatively devoid of both living coral and algae. The outer portions of this zone appear to experience periodic scouring from the forces of storm waves acting on loose bottom rubble, with subsequent impact on sessile organisms. Coral cover in this zone is less than one to two percent. The channel walls and reef slopes, with water depths of 1.8 m (6 ft) and deeper, support greater diversity and abundance of marine life, including a higher density of living corals. Coral coverage ranges from two to five percent on the slope edge to 25 percent or greater on the deeper slope in the channel. At depths of 11 m (35 ft) to 12 m (40 ft) and deeper, the bottom is characteristically sand and limestone fragments with essentially no coral development. Below approximately 15 m (50 ft), which is the channel project dredging limit, a sand and rubble zone occurs with an occasional "patch reef" structure of accreted limestone appearing among the coral rubble, on which corals colonize. These solid structures comprise about five to ten percent of the bottom, with aggregate coral cover on these structures comprising two to five percent of the bottom area. This zone extends to a depth of less than 21 m (70 ft), a horizontal distance of less than 152 m (500 ft). The outfall diffuser area is in waters of 21 to 46 m (70 to 150 ft) just east of the channel entrance, where a mixed coral rubble-sand bottom at the top of the zone merges into gray sand in the deeper portions.

The density of the fish communities varies along the proposed outfall route. Although fish have been observed on the reef flat area during previous surveys, they were not abundant. Within the coral spur and groove and sand rubble zone area (see Figure 3.4-1), fish were observed in larger numbers. In fact, fish are common in these areas. The types of fish observed include goatfish (*Mullidae*), wrasses (*Laborides phthirophagus, Pseudocheilinus octotaenia, Pseudojuloides cerasinus*), damselfish (*Pomacentridae*), and mackerel scad (*Decapterus macarellus*).

As discussed in Section 2.2.2.3, Essential Fish Habitat (EFH) is defined as waters and substrate required for fish so that they can spawn, breed, feed, or grow, and within EFH are Habitat Areas of Concern (HAPC), which are areas believed to be of particular importance or sensitivity. The proposed outfall alignment traverses areas identified as EFH, and the diffuser portion of the outfall pipe falls within the depth range (46 m [150 ft]) of a HAPC for bottomfish.

3.6 Cultural Resources

The Fort Kamehameha area forms the seaward zone of the *ahupua'a* of Halawa, the easternmost land division in the Ewa district. The historical and cultural resources of the Fort Kamehameha area are discussed in this section, with brief information on the role of this location during precontact Hawaiian, postcontact Hawaiian, and American periods.

3.6.1 Brief History[25]

Three fishponds previously existed in the vicinity of the WWTP and were named *Loko Keoki*, *Loko Waiaho*, and *Loko Lelepaua*. These ponds, located 0.6 to 2.0 km (0.4 to 1.2 mi) southeast of the WWTP site, were used to cultivate fish and were the property of the high chiefs. Some of the larger ponds were maintained by caretakers who lived near the ponds. Although the exact construction dates are unknown, they were believed to have been built during the period prior to European contact in 1778. These ponds then underwent systematic filling from the 1870s to early 1900s, and probably no longer existed by 1919. Queen Emma maintained a residence near these fishponds from the 1870s until her death in 1885.[26] In fact, *Loko Waiaho* was also known as Queen Emma's pond.

Around 1900, the Honolulu Plantation Company expanded sugar production into the Fort Kamehameha area. In 1906, Watertown, a housing camp for dredge and dock workers employed at Pearl Harbor, was established north of Fort Kamehameha. The community grew and eventually became known for gambling. The town was demolished for airport improvements in 1935. These airport expansions also brought an end to sugar production in this area.

Fort Kamehameha was acquired by the military in 1907, and beginning in 1908, dredge spoils from Pearl Harbor were deposited throughout the adjacent wetlands. From 1913 to 1915, the housing, various gun batteries, and the connecting railway system were completed. Now, most of Fort Kamehameha serves as housing for military personnel, and the gun batteries serve as offices and storage space. Northwest of the housing area is the WWTP at Fort Kamehameha.

3.6.2 Present Cultural Resources

Cultural resources (which include archaeological and historical artifacts or places of significance) in the vicinity of the WWTP are present on land in both surface and subsurface conditions. Subsurface sites include both precontact and historic cultural remains and burials. Surface sites include the historic Battery District associated with Fort Kamehameha and the historic houses. The Battery District is listed on the National Register of Historic Places, while the houses have been determined eligible for listing on the Register.

Archaeological investigations conducted in support of the WWTP expansion project resulted in the identification and recovery of subsurface cultural remains such as precontact and historical artifacts, pit features, and burials. Archaeological data recovery and treatment of burials were carried out in conformance with a 1992 Memorandum of Agreement (MOA) among the Navy, the State Historic Preservation Officer, and the Advisory Council on Historic Preservation. The MOA was prepared in consultation with the Office of Hawaiian Affairs and Hui Malama I Na Kupuna O Hawaii Nei.

3.7 Land Use

Different land areas would be involved in the construction and operation of the proposed project and its alternatives. Construction activities for the proposed action involve the western shoreline area of Hickam AFB, which is owned by the U.S. Air Force.

[25]Conrad Erkelens and J. Stephen Athens (March 1992) *Archaeological Review and Recommendations for the Fort Kamehameha Sewage Treatment Plant Expansion and Housing Relocation Plans;* P. Christian Kleiger (December 1995) *Nā Maka o Hālawa Ahupua'a, Oahu*. Prepared for State of Hawaii Department of Transportation.

[26]Queen Emma was the wife of Kamehameha IV Alexander Liholiho.

The underground injection alternative considers using the undeveloped area southeast of the WWTP for an injection well field (see Figure 2.3-1). This area, which has been designated a jurisdictional wetland, is mostly barren with some vegetation along its southwestern border. A distribution system for this alternative would have to be constructed to convey the effluent to the disposal site. Areas throughout Hickam AFB, including housing areas and various other land areas, would potentially be within the project area.

3.8 Socioeconomic Environment

3.8.1 Economic Activities and Surrounding Communities

The Fort Kamehameha project area is located in a region where the primary economic endeavors are agriculture, commercial and industrial enterprises, and military activities. Major land areas in the vicinity of the WWTP include Hickam AFB, Honolulu International Airport, the Pearl Harbor Naval Complex, and the communities of Salt Lake, Moanalua, Pearl City, Waipahu, and Waipio.

3.8.2 Military Population

In 1996, the Pearl Harbor Naval Complex employed approximately 18,100 active military personnel and approximately 7,600 civilian employees;[27] Hickam Air Force Complex, including Hawaii Air National Guard (HIANG) facilities at Hickam, employed approximately 4,920 full-time active military personnel and approximately 1,850 full-time civilian employees.[28] While reduction in forces has decreased these employee numbers somewhat in recent years, military personnel numbers may again increase. The WWTP at Fort Kamehameha has been recently expanded to meet these fluctuations and to provide the treatment capacity to handle anticipated peak flows.

3.8.3 Ocean Activities

A site-specific survey was conducted in the months of October through December of 1996. The purpose of the survey was to provide background information about ocean activities in the vicinity of the proposed outfall location. The results of the survey are summarized below and included in Appendix IX. Subsequently, an advisory warning against eating fish and shellfish from Pearl Harbor and urban streams in Honolulu was issued by DOH in August 1998.

Ocean activities occurring in the possible region of influence of the WWTP outfall include personal consumptive, commercial, and recreational undertakings. Such activities as netting, fishing, trapping, tropical fish collecting, surfing, scuba diving, paddling, kayaking, and shelling occur in this area. A more detailed discussion of these various ocean activities is included in Section 4.5 and Appendix IX.

Ocean activities occur most commonly between the Reef Runway and the Pearl Harbor Entrance Channel and are usually concentrated on the shoreline at the Hickam Outdoor Recreational Facility (which includes Honeymoon Beach Park, Hickam Beach Park, and Hickam Harbor), the Hickam Wetland Management Area, and the Fort Kamehameha housing area (see Figure 4.5-1 for locations). Even though the beach at Hickam Beach Park is small and the water is murky, most

[27] Written communication with staff, Public Affairs Office, COMNAVBASE, Pearl Harbor (August 28, 1997); Verbal communication with staff, Public Affairs Office, COMNAVBASE, Pearl Harbor (August 28, 1997).

[28] Verbal communication with staff, Hawaii Air National Guard Headquarters (August 28, 1997); Written communication with staff 15th Air Base Wing, Public Affairs Office (August 26, 1997).

activities occur here because it is easily accessible by nearby military personnel. Offshore activities are concentrated on the shallow reef flat or reef slope (see Figure 4.5-1).

Because the military has jurisdiction over the Pearl Harbor Defensive Sea Area (see Figure 1.6-1), the Pearl Harbor Entrance Channel and Hickam Harbor are restricted to vessels owned and operated by military or Department of Defense (DoD) personnel. Several commercial fishing and tour boats have been authorized to operate in the Pearl Harbor vicinity. Civilian watercraft are not allowed inshore of the Reef Runway.

DoD personnel, their family members, and guests may fish recreationally in certain Navy-owned and Air Force-owned areas. In August 1998, the DOH issued an advisory regarding the consumption of fish and shellfish from Pearl Harbor. The Navy and Air Force have posted signs along the shoreline of Pearl Harbor informing DoD personnel and the general public of this advisory.

3.9 Utilities

3.9.1 Water Supply

3.9.1.1 Potable Water

The Navy potable water system in the Pearl Harbor area has two primary groundwater sources, Waiawa and Red Hill, with a third groundwater source at Halawa maintained for backup purposes. Waiawa, Red Hill, and Halawa Tunnel have maximum effective pumpage capacities of 102,000 m^3/day (27 mgd), 719,000 m^3/day (190 mgd), and 26,500 m^3/day (7 mgd), respectively. Assuming normal rainfall conditions, the assessed sustained pumping yield of the Navy supply sources is 157,000 m^3/day (41 mgd). Two 23,000 cubic meter (m^3) (6 million gallon [gal]) tanks at Halawa store fresh water for peak demands and any emergencies. Four other storage tanks hold 4,900 m^3 (1.3 million gal) of water, collectively. Freshwater distribution lines are located throughout the Pearl Harbor Naval Complex. The Navy's water system is interconnected with the Board of Water Supply (BWS) system to increase the flexibility of the Navy system, especially in times of emergency. On average, an estimated 42,000 m^3/day (11 mgd) of potable water from the Pearl Harbor water system is used at Pearl Harbor.[29] The Pearl Harbor water system also supplies Hickam AFB with potable water. Hickam AFB uses approximately 8,300 m^3/day (2.2 mgd) of potable water.[30]

Potable water is provided to the WWTP through a 30-cm (12-inch)-diameter pipe under Fort Kamehameha Road which supplies potable water to Hickam AFB. The WWTP uses potable water mainly for maintenance and cleanup within the plant.

3.9.1.2 Nonpotable Water

Between July 1994 and June 1995, the Pearl Harbor district, which includes Waipio, Mililani, Waipahu, Waiawa, Pearl City, Waimalu, and Aiea, used approximately 1,010 m^3/day (267,000 gal/day) of nonpotable water from the BWS for irrigation purposes.[31] Nonpotable water is not currently being used at Pearl Harbor Naval Complex or Hickam AFB.

[29]Verbal communication with Environmental Engineer, Navy Public Works Center (March 25, 1997).

[30]Verbal communication with Environmental Engineer, Hickam Air Force Base (May 13, 1997).

[31]City and County of Honolulu, Board of Water Supply (no date) *Annual Report and Statistical Summary July 1, 1994 - June 30, 1995.*

The Honolulu International Airport presently uses an average of approximately 36,000 m^3/day (9.5 mgd) of nonpotable groundwater for irrigation purposes. Although only potable water is presently being used, consideration is currently being given to the use of nonpotable water for irrigation of the Navy-Marine Golf Course within the Pearl Harbor Naval Complex.[32] Plans to supply nonpotable irrigation water to the Hickam Mamala Bay Golf Course are currently being pursued by Hickam AFB and the BWS.[33]

3.9.2 Sewer System

The Pearl Harbor Naval Complex and Hickam AFB each have sanitary sewer systems consisting of gravity mains and sewage lift stations. Flow generated by the Hickam Complex is pumped to the WWTP at Fort Kamehameha from the main Air Force sewage pump station. Flow generated by the Pearl Harbor Complex is pumped to the WWTP from the main Navy sewage pump station.

3.9.3 Electricity

Electrical power for the Pearl Harbor Naval Complex is provided by Hawaiian Electric Company. There are two sources of primary power to the WWTP: an 11.5 kilovolts (kV) Fort Kamehameha circuit and an alternate 11.5 kV circuit servicing the HIANG. These two feeder lines come from a substation at Hickam AFB and bring power into the existing 1,000 kilovolt-amperes main transformer at the WWTP, where it is stepped down to 480 volts and distributed throughout the plant. The two primary power feeders and the existing transformer have the capacity to operate the entire plant. Two generators, 600 kilowatt (kW) and 1400 kW, are maintained as a third source of power in case of emergency.

3.10 Navigation

Executive Order 8143 established the Pearl Harbor Defensive Sea Area (see Figure 1.6-1) and prohibits civilian watercraft within Pearl Harbor unless authorized by the Navy. Certain areas of the harbor also have additional restrictions because of naval navigational concerns, explosive hazards, or security requirements.

In addition to regulatory constraints, other constraints pertaining to navigation include the depth, width, and overhead clearance of navigable channels within Pearl Harbor and existing uses of the harbor. The width of the entrance channel varies from approximately 500 to 300 m (1,600 to 1,000 ft), while the depth ranges from 45 to 12 m (150 to 40 ft) in the area of the proposed outfall. There are no overhead obstructions to navigation at the entrance.

In addition to the passage of naval vessels, navigational uses of Pearl Harbor include authorized tour boats, military recreational boating from Rainbow Bay Marina (in Aiea Bay), and emergency vessels.

3.11 Roads and Traffic

Access to the WWTP site is via Fort Kamehameha Road, a paved, two-lane road within Hickam AFB. Aligned in a northwest-southeast direction at the WWTP, the road runs from Vickers Avenue to the Hickam Golf Course. The Hickam AFB main entrance gate is located on Vandenberg

[32]Verbal communication with Maintenance Supervisor, Navy-Marine Golf Course (April 1997).

[33]City and County of Honolulu, Board of Water Supply (March 1996) *Final Environmental Assessment for Hickam Golf Course Non-Potable 12-Inch Water Main.*

Avenue. All roads in Hickam AFB are in good condition. No problems with traffic congestion have been reported in the vicinity of the WWTP.

3.12 Aviation

Areas within the Fort Kamehameha region are subject to aviation influences from the runways at Hickam AFB and Honolulu International Airport. Besides aircraft noise from both Honolulu International Airport and Hickam AFB, the potential for aircraft accidents is a specific consideration in determining the compatibility of land uses surrounding an air installation. Several approaches to runways at Hickam AFB/Honolulu International Airport pass over the project site. The elevation of vertical obstructions to air navigation at the site is managed by the U.S. Air Force and the Federal Aviation Administration.

3.13 Existing Ordnance

Military munitions that have been primed, fuzed,[34] armed, or otherwise prepared for action, and have been fired, dropped, launched, projected, or placed in such a manner as to pose a hazard to operations, installation, personnel, or material and remain unexploded either by malfunction, design, or for any other cause are referred to as unexploded ordnance (UXO).[35] The hazardous context is an important distinction for an Explosive Ordnance Disposal (EOD) response since not all UXO is equally hazardous. The hazardous state definition generally includes dud-fired ordnance and munitions that have deteriorated or been damaged so that normal handling procedures are risky, and includes deployed "inert" ordnance, as these items may have intact pyrotechnic spotting charges. UXO in the marine environment would generally be considered hazardous.[36] A distinction can be made between "UXO" and "dumped ordnance" (i.e., ordnance for which the fuze typically had not been actuated nor the ordnance projected downrange) because dumped ordnance would normally be considered less hazardous than UXO. However, in the underwater environment with lack of sufficient information, even dumped ordnance must be considered and treated as "UXO" until determined by EOD experts to be otherwise.

Two ordnance items were observed during a benthic survey in October 1998. One ordnance item was an 11.3 kg (25 lb) World War I era practice bomb. It was located in approximately 1.5 m (5 ft) of water along the microtunneling segment. This item was identified as nonhazardous and subsequently removed. The second ordnance item was a 6-inch diameter projectile located just west of the outfall alignment, in the entrance channel. This item was also eventually removed. Based on these findings, historical research of the area was conducted. According to the research, dumping munitions–usually unfuzed or unactuated–from Navy vessels did occur. Such actions were done as a matter of convenience prior to the 1970s. Even though it is possible that dumped munitions are present in and around Pearl Harbor, it is extremely unlikely that they have worked their way onto the shallow reef areas where land-based trenching activities will occur.

In addition, research revealed that the area seaward of the current WWTP was used as a firing range for Fort Kamehameha and an associated Gun Park area during the 1920s to 1940s. There were four major batteries within the Fort Kamehameha and Gun Park areas.[37] Guns were also mounted on rail cars within the fort. Guns used at the fort included 7.6-cm (3-in), 15.2-cm (6-in),

[34]This spelling is conventionally used with reference to ammunition.

[35]Department of Defense (February 21, 1996 revised September 13, 1996) *Draft Proposed Military Range Rule*. Volume 61, Federal Register, p. 6,588.

[36]A. Pederson (April 1997) *The Challenges of UXO in the Marine Environment*. Conference Proceedings of the UXO Forum, Nashville, TN.

[37]W. Dorrance (May 1993) *Fort Kamehameha, The Story of the Harbor Defenses of Pearl Harbor.*

and 30.5-cm (12-in) types. There have also been several Army Coastal Defense Artillery batteries within range, at one time or another, of all portions of the area under consideration for the outfall. The Army terminated this function nationally by 1948. Therefore, it is possible that different types of ordnance, whether fired from batteries or dumped from Navy vessels, may be located at any point along the proposed outfall alignment.

A wide variety of munition calibers may potentially be located in the battery impact areas with the majority being subcaliber and inert. The inert major caliber rounds were fired for service practice. Thus, it is likely that more inert projectiles may be located in the battery impact areas than live, unexploded projectiles. However, not all the projectiles fired were inert. For example, a battery at Ahua Point fired 155 mm projectiles and there were no drill or practice firing projectiles for that time period.[38] As indicated above, deployed inert ordnance is included in the hazardous state definition, as these items may have intact pyrotechnic spotting charges.

Typically, projectiles fired during practice passed over and beyond the project site. The area under consideration for this project is located within approximately 3.4 km (2.1 mi) of the practice ranges. The minimum ranges for major caliber "service practice" exercises were determined to be about 4.5 km (2.8 mi), which is well offshore of the area under consideration. However, it is possible that gun batteries not considered part of Fort Kamehameha were present and firing into the area of concern. In addition, subcaliber rounds may still be expected within the area, although designation of such a close-in firing area is not likely for safety reasons. The Army shore batteries should have fired most of their rounds outside of the area of the proposed alignment construction corridor. Therefore, most practice rounds are believed to have impacted beyond the area of the proposed outfall construction corridor.

A more detailed diving/visual and magnetometer survey was performed in March-April 1999 to estimate the number of ordnance items that might exist within the project construction corridor. The portion of the alignment that will be microtunneled was not surveyed since trenching would not be conducted in this area, and it is unlikely that ordnance items are located at a depth of 4.9 to 9.8 m (16 to 32 ft) below the coralline substrate. The results of the magnetometer survey were inconclusive primarily due to the large quantities of metallic debris in the area. However, during diving/visual observations, one inert (hollow) 6-inch projectile was discovered along the channel edge and five more 6-inch projectiles were discovered in the survey area.

In August 1999, the Navy Explosive Ordnance Disposal Mobile Unit Three detachment disposed of the six projectiles discovered during the survey. These projectiles were found to be unfired and were removed from the water, transported to Schofield Barracks, and destroyed following established protocols. Of the six projectiles removed from the site, five did not contain any form of fuzing and were considered to be inert. The sixth projectile contained a fuze, but had not been fuzed or prepared for action, which typically occurs upon firing. All of the projectiles were probably used for training and dumped at the location circa 1914.

Based on these observations and information from other dives conducted in the area, there are no known ordnance items within the construction corridor.

[38] U.S. Army (29 July 1940) *Seacoast Artillery; Organization and Tactics.* War Department, Coast Artillery Field Manual, FM 4-5.

CHAPTER FOUR

ANALYSIS OF IMPACTS AND MITIGATION

CHAPTER FOUR
ANALYSIS OF IMPACTS AND MITIGATION

4.1 Introduction and Organization of this Chapter

This chapter identifies and compares the anticipated environmental impacts of the proposed action the underground injection, and no-action alternatives, as described in Chapter 2. These impacts are evaluated for significance with consideration given to the proposed mitigative actions.

The issues identified during the scoping process were screened for potential significance using relevant measures of effect. Issues that were identified as significant as a result of this initial screening were evaluated in further detail. Proposed mitigation has been identified for each potential impact, and the mitigated impacts were analyzed relative to existing conditions using specific parameters and factors.

The categories of issues identified during scoping as potentially significant, listed below, are discussed in Sections 4.4 through 4.10:

- Effects on the aquatic environment,
- Socioeconomic effects,
- Effects on protected species,
- Cultural issues,
- Public health issues,
- Navigational impacts, and
- Water as a resource.

For each category, the potential significance of the direct and indirect impacts and cumulative effects of project-related impacts with relevant non-project-related impacts are analyzed.

4.2 Significance Factors and Evaluation Parameters

4.2.1 Screening of Issues

Council on Environmental Quality (CEQ) regulations require that an environmental impact statement (EIS) evaluate the relevant and potentially significant impacts of a proposed action on both natural and human environments. The potential issues are determined during scoping, which includes public comment. The list of possible issues is then screened for relevance. An issue is considered relevant if an impact associated with it is a foreseeable consequence of the action or results in a foreseeable consequence when viewed cumulatively with impacts of any other action.

CEQ regulations require that the following factors be considered in determining whether an issue requires evaluation under the National Environmental Policy Act (NEPA):

- Affects public health and safety.
- Affects unique characteristics of a geographic area (historical/cultural resources, wetlands, ecologically critical areas, wild/scenic rivers, parks).
- Is highly controversial.
- Involves highly uncertain, unique, or unknown risks.

- Establishes a precedent.
- Generates cumulatively significant effects.
- Involves sites listed or with the potential to be listed on the National Register of Historic Places.
- Affects plants or animals listed as threatened or endangered under the Endangered Species Act.
- May violate laws or requirements imposed for protection of the environment.

4.2.2 Significance Factors

CEQ regulations, 40 Code of Federal Regulations (CFR) 1500 to 1508, provide guidelines for evaluating the significance of impacts resulting from an action. These guidelines include the following considerations for determining whether a potential impact is significant:

- Absolute value of change.
- Relative amount of change.
- Effect of the change on a resource, population, or condition.
- Duration of the effect.
- Geographic extent of the effect.
- Affected population.

These factors are applied to the foreseeable direct, indirect, and cumulative impacts of the proposed action and the underground injection and no-action alternatives. Speculative consequences do not have to be evaluated. A worst-case analysis is not required, but conservatism is employed throughout this document in performing calculations and estimating impacts.

4.2.3 Parameters Selected for Evaluation

The intent of CEQ regulations is to evaluate the significance of potential environmental impacts resulting from an action. Parameters have therefore been established to evaluate impacts related to each relevant and potentially significant issue. The parameters or conditions have been measured by comparing anticipated impacts with the factors used to determine significance. The parameters selected and the methods of evaluation were chosen to facilitate comparison among alternatives and to measure relative and absolute change induced by the action. The absolute change has been compared with regulatory standards, where applicable. The initial screening criteria selected for this EIS are presented in Table 4.2-1.

Each of the relevant and potentially significant issues analyzed in the following sections is preceded by a discussion of parameters or conditions selected for evaluation and the evaluation methodology. These parameters are summarized below:

- **Aquatic Environment** - Whether water quality is changed, size and location of the potential zone of mixing (ZOM), and the rate of contaminant discharge to receiving waters; whether the marine environment is changed, size of bottom area directly impacted, area of living coral affected, and duration of each impact.

- **Socioeconomics** - Project cost, recreational activities affected, economic activities affected, population affected, assured continuation of wastewater disposal services, and duration of each impact.

Table 4.2-1
Initial Screening of Issues

TOPIC	ISSUE	SCREENING CRITERIA	RELEVANT ISSUES?			DISPOSITION
			Replacement Outfall	Underground Injection	No Action	
PHYSICAL ENVIRONMENT						
Soils	Adequate support of proposed structures by existing soils	Geotechnical design standards and geotechnical engineer's recommendations	No - infeasible options will be eliminated; designs will provide adequate support	No - design will provide adequate support	No - new structures are not proposed	No additional evaluation required
	Potential acceleration of erosion by construction	Area of firm land disturbed, compliance with Clean Water Act (CWA)	No - Best Management Practices (BMPs) will be followed	No - BMPs will be followed	No - construction not proposed	
	Potential degradation or impairment of the agricultural value of any land	Mapped agricultural value of land	No - agricultural lands not affected	No - agricultural lands will not be used	No - agricultural lands not affected	
Unique Land Forms	Potential damage to unique land forms	Presence of unique land forms	No - unique land forms not present			No additional evaluation required
Flooding/ Tsunami Inundation	Location in a flood zone or tsunami inundation area	Presence in zone, compliance with Executive Order 11988	No - design will mitigate potential flooding/tsunami impacts	No - design will mitigate potential flooding/tsunami impacts	No - new structures not proposed; existing outfall was built to withstand flooding/ tsunami impacts	No additional evaluation required

Table 4.2-1 *(continued)*

TOPIC	ISSUE	SCREENING CRITERIA	RELEVANT ISSUES?			DISPOSITION
			Replacement Outfall	Underground Injection	No Action	
PHYSICAL ENVIRONMENT *(continued)*						
Seismic Hazards	Ability of proposed structures to withstand seismic activity characteristic of Oahu	Compliance with Uniform Building Code (UBC)	No - construction will comply with UBC	No - construction will comply with UBC	No - construction not proposed	No additional evaluation required
Surface Water Quality	Potential degradation of existing surface water quality	Size and location of ZOM, percent of time that plume surfaces, compliance with Hawaii Administrative Rules (HAR) 11-54 water quality standards, CWA, and Department of Health (DOH) permits, regulations, and guidelines	Yes - positive impact of removing discharge from Pearl Harbor Estuary, negative impact of discharge to Open Coastal Waters within the ZOM	Possibly - information required to assess potential impact of injection of effluent into groundwater on coastal waters is unavailable	Yes - increase in effluent discharge volume could cause violations of water quality standards	See Section 4.4 for additional evaluation
	Potential impact upon ocean users	DOH criteria for recreational waters, whole effluent toxicity, plume visitation frequency, effluent chemistry, accumulation of toxic chemicals, location and duration of construction	Yes - potential for presence of pathogens or toxins from the effluent in open coastal recreational waters	Possibly - information required to assess potential impact of injection of effluent into groundwater on coastal waters is unavailable	Yes - potential for presence of pathogens or toxins from the effluent in Pearl Harbor Estuary and open coastal recreational waters	See Section 4.8 for additional evaluation

Table 4.2-1 *(continued)*

TOPIC	ISSUE	SCREENING CRITERIA	RELEVANT ISSUES?			DISPOSITION
			Replacement Outfall	Underground Injection	No Action	
PHYSICAL ENVIRONMENT *(continued)*:						
Groundwater	Potential degradation of existing groundwater quality	Presence of contaminant source, routes of access, compliance with Resource Conservation and Recovery Act (RCRA) and water quality standards	No - will discharge to Open Coastal Waters of Mamala Bay	Possibly - information required to evaluate impact is unavailable	No - presently discharges to the Pearl Harbor Estuary	See Section 4.10 for additional evaluation
	Potential impairment of the freshwater lens or increased saltwater intrusion	Magnitude of impact on freshwater lens	No - will discharge to Open Coastal Waters of Mamala Bay	No - mitigation by compliance with DOH regulations	No - presently discharges to the Pearl Harbor Estuary	No additional evaluation required
Air Quality	Potential increase of air emissions or degradation of existing air quality	Change in emissions	No - construction vehicles and equipment not considered major stationary sources; some equipment may be regulated as non-covered sources by the Department of Health and therefore be required to comply with standard operating requirements		No - no new emissions anticipated	No additional evaluation required
	Compliance with provisions of the Clean Air Act (CAA)	Compliance with CAA	No - State of Hawaii is in attainment of national and state air quality standards			No additional evaluation required
Noise	Potential to generate noise incompatible with existing site and nearby land use	Change in area noise level, presence of sensitive receptors, compliance with local noise ordinances	No - short-term, construction-related only; mitigated by compliance with DOH regulations		No - construction not proposed	No additional evaluation required

Table 4.2-1 *(continued)*

TOPIC	ISSUE	SCREENING CRITERIA	RELEVANT ISSUES?			DISPOSITION
			Replacement Outfall	Underground Injection	No Action	
BIOLOGICAL RESOURCES						
Endangered Species	Potential to adversely affect or "take" listed species or have the potential to impact endangered species	Presence at site, compliance with Endangered Species Act, and Marine Mammal Protection Act	Yes - turtles, listed species of birds	Possibly - depends on site location	No - construction not proposed; existing discharge not known to impact listed or endangered species	See Section 4.6 for additional evaluation
Migratory Birds	Potential to adversely affect migratory birds and their habitat	Presence at site, compliance with Executive Order 13186	No - active construction will avoid areas that migratory birds are known to visit	Possibly - construction activities could impact migratory bird habitat	No - construction not proposed; existing discharge not known to impact migratory birds	See Section 4.6 for additional evaluation
Wetlands and Habitat	Potential to adversely affect wetlands and protected habitats	Presence at site, compliance with Executive Order 11990	No - active construction will avoid wetland areas; discharge will be removed from the Pearl Harbor Estuary	Yes - proposed injection well field located in a jurisdictional wetland	Possibly - increased effluent discharge could impact aquatic habitat	See Section 4.6 for additional evaluation
Coral Reefs	Potential to adversely affect coral reef ecosystems	Presence, size of area affected, percent living coral coverage, compliance with Executive Order 13089	Yes - construction activity in living coral habitat	No - ocean-based construction not proposed	Possibly - increased effluent discharge could impact aquatic habitat	See Sections 4.4 and 4.6 for additional evaluation
Introduced Species and Disease	Potential to introduce new noxious species or diseases	Volume and types of materials transported and number of trips from a source area of new species/disease	No - shipment of construction materials/ equipment to Hawaii will comply with all State regulations		No - construction not proposed	No additional evaluation required

Table 4.2-1 *(continued)*

TOPIC	ISSUE	SCREENING CRITERIA	RELEVANT ISSUES?			DISPOSITION
			Replacement Outfall	Underground Injection	No Action	
BIOLOGICAL RESOURCES *(continued)*:						
Essential Fish Habitat (EFH)	Potential to adversely affect those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity	Presence at site, compliance with Magnuson-Stevens Act/Sustainable Fisheries Act	Yes - project area has been designated EFH; diffuser portion of outfall pipe falls within the depth range of a Habitat Area of Particular Concern (HAPC) for bottom fish	No - ocean-based construction not proposed	Possibly - increased effluent discharge could impact aquatic habitat	See Section 4.6 for additional evaluation
Marine Biota	Potential to adversely affect marine biota	Marine biota present, size of area and duration of construction disturbance, size and location of ZOM, compliance with HAR 11-54 water quality standards and CWA	Yes - short-term impacts during construction and possible long-term impacts during operation	Possibly - depends on groundwater flow from injection wells to coastal waters	Possibly - increase in wastewater volume could violate water quality standards	See Section 4.4 for additional evaluation
CULTURAL RESOURCES						
Archaeological Resources	Potential to damage significant archaeological resources or destroy significant data	Presence, significance under National Historic Preservation Act (NHPA), compliance with NHPA	No - proposed alignment does not cross any possible archaeological sites	Possibly - construction in areas not previously surveyed	No - construction is not proposed	See Section 4.7 for additional evaluation
Burials	Potential to encounter human remains	Length/area of excavation on firm land, compliance with Native American Graves Protection and Repatriation Act (NAGPRA)	No - burials unlikely to be located on the reef flat; construction area on shore has been previously surveyed	Possibly - construction in areas not previously surveyed	No - construction is not proposed	See Section 4.7 for additional evaluation

Table 4.2-1 *(continued)*

TOPIC	ISSUE	SCREENING CRITERIA	RELEVANT ISSUES?			DISPOSITION
			Replacement Outfall	Underground Injection	No Action	
CULTURAL RESOURCES *(continued)*:						
Historical Resources and National Historic Landmarks	Potential to affect significant historic structures or damage or destroy significant historic data	Presence, significance under NHPA, compliance with NHPA	No - historical resources and National Historic Landmarks are not present along the proposed alignment	Possibly - construction in areas near to historic structures	No - WWTP does not affect any historic resources or national historic landmarks	See Section 4.7 for additional evaluation
LAND USE						
Land Use Compatibility	Incompatibility with surrounding land uses	Change in land use	Yes - temporary impacts on recreational and commercial use of ocean in area of outfall	No - alternative would be consistent with use	No - change in land use is not anticipated	See Section 4.5 for additional evaluation
Visual Impacts	Potential to interfere with important views	Presence of valued view, changed views from surrounding communities	No - short-term impacts during construction only	No - construction impacts would be short- term; visual impact of injection well backwash structures would be mitigated by appropriate design criteria	No - alternative does not interfere with views	No additional evaluation required

Table 4.2-1 *(continued)*

TOPIC	ISSUE	SCREENING CRITERIA	RELEVANT ISSUES?			DISPOSITION
			Replacement Outfall	Underground Injection	No Action	
INFRASTRUCTURE						
Potable Water Supply	Potential degradation or reduction in existing water supply	Change in demand, transmission capacity, source of contaminants, compliance with Safe Drinking Water Act	No - alternative will not affect the potable water supply			See Section 4.10 for additional evaluation
Storm Water Drainage and Storage	Potential to interfere with or overload existing storm water drainage capacity	Change in volume of storm water generated, volume of storage available, source of potential contaminants, compliance with CWA	No - alternative will not affect the storm water drainage and storage	Possibly - proposed injection well field located in a jurisdictional wetland	No - alternative will not affect the storm water drainage and storage	See Section 4.6 for additional evaluation
Wastewater Disposal	Potential to interfere with or overload existing wastewater treatment capacity	Change in volume or quality of wastewater generated	No - alternative will not alter the volume or quality of wastewater generated			No additional evaluation required
Solid Waste Disposal	Potential to interfere with or overload existing solid waste transportation and disposal facility capacity	Change in volume or type of waste generated, compliance with RCRA	No - alternative will not alter the volume or type of waste generated			No additional evaluation required

Table 4.2-1 *(continued)*

TOPIC	ISSUE	SCREENING CRITERIA	RELEVANT ISSUES?			DISPOSITION
			Replacement Outfall	Underground Injection	No Action	
INFRASTRUCTURE *(continued)*						
Hazardous Waste Disposal	Potential to interfere with or overload existing hazardous waste transportation, storage, and disposal facility capacity	Change in volume or nature of hazardous waste generated, compliance with RCRA	No - BMPs and Standard Operating Procedures (SOPs) will be followed; all applicable regulations will be complied with		No - alternative does not produce hazardous waste	No additional evaluation required
Electricity and Power	Potential change in demand or system/ transmission capacity of existing electric power supply	Change in demand	Yes - use of energy for pumping will increase			See Sections 2.2 through 2.4, 4.11.1.3, and 4.18 for additional evaluation
Telephone and Communications	Potential change in demand or system/ transmission capacity of existing tele-communications system	Change in demand	No - alternative will not alter the demand of the existing telecommunications system			No additional evaluation required
Roads and Traffic	Potential change in traffic conditions at existing intersections	Change in number/type of vehicles, change in level of service	No - short-term impacts during construction only; mitigated by posting of appropriate signs		No - alternative will not affect road/traffic conditions	No additional evaluation required
Housing	Potential change in demand for or supply of residential units	Change in demand or supply	No - alternative will not alter the demand for or supply of housing units			No additional evaluation required

Table 4.2-1 *(continued)*

TOPIC	ISSUE	SCREENING CRITERIA	RELEVANT ISSUES?			DISPOSITION
			Replacement Outfall	Underground Injection	No Action	
INFRASTRUCTURE *(continued)*:						
Public Services	Potential overload of existing police, fire, medical, or emergency services	Change in demand for these services	No - additional police, fire, medical, or emergency services not required			No additional evaluation required
SOCIOECONOMIC ENVIRONMENT						
Economic Activity	Potential to adversely affect those who derive economic benefit from the project area (commercial recreation and fishing enterprises) or local housing prices	Magnitude of change in projected revenues over a period of time based on size, location of ZOM and percent of time that plume surfaces	Possibly - impact of ZOM and presence of discharge on commercial activities in area around diffuser	Possibly - dependent on impact of injection on coastal waters	Possibly - increase in wastewater volume could violate water quality standards	See Section 4.5 for evaluation
Environmental Justice	Potential to disproportionately affect minority or economically disadvantaged populations	Presence of such population in or near vicinity of proposed action, compliance with Executive Order 12898	No - alternative not located in the vicinity of such populations			See Section 4.5 for additional evaluation
Recreational Activity	Potential adverse effect on those who derive recreational benefit from the project area	Magnitude of effect on recreational use in project area	Yes - temporary displacement of recreational activities during construction; operation may affect activities in area around diffuser	Possibly - dependent on impact of injection on coastal waters	Possibly - increase in wastewater volume could violate water quality standards	See Section 4.5 for additional evaluation

Table 4.2-1 *(continued)*

TOPIC	ISSUE	SCREENING CRITERIA	RELEVANT ISSUES?			DISPOSITION
			Replacement Outfall	Underground Injection	No Action	
SOCIOECONOMIC ENVIRONMENT *(continued)*:						
Government Services	Potential increase in demand for government services	Change in demand for government services	No - alternative would not increase demand for government services			No additional evaluation required
Fiscal Resources	Potential adverse fiscal effects	Cost	Yes - substantial construction costs	Yes - substantial construction and operation costs	Possibly - fines from potential water quality violations	See Sections 2.2 through 2.4 for additional evaluation
MAN-MADE HAZARDS AND CONSTRAINTS						
Construction Sites	Safety of public in and around equipment and excavations	Accessibility	No - public access will be restricted at construction sites		No - construction is not proposed	No additional evaluation required
Storage Tanks	Addition or modification of underground storage tanks or aboveground storage tanks at the site	Change in tanks, compliance with RCRA	No - addition or modification of underground or aboveground storage tanks not required			No additional evaluation required
Hazardous Materials Storage	Addition or modification of hazardous materials storage areas	Change in amount or type of hazardous materials stored, change in spill prevention capability, consistency with RCRA	No - BMPs and SOPs will be followed; all applicable regulations will be complied with		No - alternative does not involve hazardous materials	No additional evaluation required

Table 4.2-1 *(continued)*

TOPIC	ISSUE	SCREENING CRITERIA	RELEVANT ISSUES?			DISPOSITION
			Replacement Outfall	Underground Injection	No Action	
MAN-MADE HAZARDS AND CONSTRAINTS *(continued)*:						
Contaminated Land and Water	Potential exposure of the public to contaminated media	Change in exposure of public, receptor sensitivity, consistency with Comprehensive Environmental Response, Compensation, and Liabilities Act, Superfund Amendments and Reauthorization Act, and RCRA	Possibly - construction-related suspension of existing contaminated sediments	Possibly - construction-related excavation	No - activities which may expose public to contaminated media are not proposed	See Section 4.4 for additional evaluation
Hazards to Navigation	Potential interference with existing or future water traffic	Presence and duration of barges in channel, change in probability of ship emergency anchors damaging outfall pipe	Yes - short-term during construction in Pearl Harbor Entrance Channel	No - ocean-based construction is not proposed	No - existing outfall is located at the edge of the Pearl Harbor Entrance Channel where it does not interfere with navigation	See Section 4.9 for additional evaluation
Air Navigation	Potential for facilities/activities to be within existing airfield accident potential zones or aircraft approach/ departure zones	Presence of activity/facilities in defined zones, consistency with Federal Aviation Administration (FAA) requirements	No - all FAA requirements will be met		No - activities which may interfere with air navigation are not proposed	No additional evaluation required

Table 4.2-1 *(continued)*

TOPIC	ISSUE	SCREENING CRITERIA	RELEVANT ISSUES?			DISPOSITION
			Replacement Outfall	Underground Injection	No Action	
MAN-MADE HAZARDS AND CONSTRAINTS *(continued)*:						
Explosive Safety Quantity Distance (ESQD) Arcs and Surface Danger Zones (SDZs)	Potential of exposing personnel to explosions or weapons fire	Intersection of proposed activity or facility with existing arcs/zones	No - alternative is not located in an ESQD arc or SDZ			No additional evaluation required
Ordnance	Potential injury to personnel resulting from accidental detonation of an ordnance item	Presence of construction activities in area that possibly contains ordnance items	Yes - objects suspected of being ordnance have been removed from the construction corridor for the proposed outfall	No - construction will occur in developed/ urbanized areas; therefore, occurrence of ordnance items is unlikely	No - construction not proposed	See Section 4.8 for additional evaluation
Electromagnetic Radiation (EMR)	Potential for existing Hazards of Electronic Radiation to Persons (HERP) or Hazards of Electronic Radiation to Fuel (HERF) or ordnance (HERO) zones to intersect the proposed project area	Presence of activity/facility in zones, change in EMR generated	No - alternative is not located in EMR zones for HERP, HERO, and HERF and no change in EMR generation is anticipated			No additional evaluation required
Fire	Potential increase in the risk of fire	Change in sources of fire, change in presence of vulnerable resources	No - activities proposed will not increase the likelihood of fires or vulnerability to fires			No additional evaluation required

- **Protected Species** - Presence of protected species in affected area, type of habitat use, amount of habitat lost, duration of loss, potential for harm to individuals or species.

- **Cultural Resources** - Whether resources are present in the region of influence, type and value of resources, and potential for damage or disturbance of resources.

- **Public Health and Safety** - Presence of ordnance items in the construction corridor; whether exposure to pathogens or toxins is created, population potentially exposed, frequency of exposure, and potency of exposure.

- **Navigation** - Whether the project poses an obstruction to navigation, potential for damage to the outfall by ship anchors.

- **Potable Water Resources** - Quantity consumed and quantity conserved.

4.3 Screening of Issues for Detailed Evaluation

This section presents the issues identified during scoping, screens them for potential significance based upon specific screening criteria, and determines which issues require detailed evaluation. Table 4.2-1 lists the issues, the screening criteria used to evaluate potential significance, and the significance of each issue under the proposed action and alternatives. Issues anticipated to be nonsignificant, or for which associated impacts are easily mitigated by existing regulations or standard operating procedures, are not carried forward for further analysis of the alternatives.

4.3.1 Nonsignificant Issues

The following issues were raised in scoping but have been determined to be nonsignificant for the proposed action, underground injection, and no action. While not directly addressed, some of these matters are related to or part of other issues.

- Air quality,
- Solid waste,
- Storm water drainage,
- Aesthetics/view shed,
- Terrestrial environment,
- Government services,
- Housing,
- Telephone and communications,
- Public services, and
- Introduced species.

The rationale for a determination of nonsignificance, such as the nature of the action or its location, is provided in Table 4.2-1. Components of the terrestrial environment are covered under various physical environment and land use categories in Table 4.2-1.

4.3.2 Nonsignificant Issues Mitigated by Management Requirements

The following issues were screened for potential significance and found to be nonsignificant due to regulatory standards imposing routine mitigative or protective measures, including existing

BMPs or SOPs. Some of these issues are subsumed or considered in conjunction with other issues. The rationale for the determination of nonsignificance is presented below.

- **Soils** - The only potential soil impacts of the proposed action or the underground injection alternative would be related to stockpiling of excavated material for backfill or subsequent disposal. Application of standard stockpiling and transporting regulations would render the potential impacts from these activities nonsignificant. The no-action alternative would not impact soils because construction is not proposed.

- **Traffic** - Access to the construction staging areas for workers and vehicles hauling construction materials will be via Vandenburg Boulevard, Vickers Avenue, and Fort Kamehameha Road from the Hickam Air Force Base (AFB) Main Gate. This standard route for all traffic to the Fort Kamehameha area passes through primarily industrial areas, although there is a residential area northwest of Vickers Avenue. A maximum of approximately 30 construction workers is anticipated at any one time. The number and frequency of vehicles along this route, due to the construction of the proposed replacement outfall or the underground injection alternative, would be similar to the traffic generated for similar construction projects in the area (e.g., the recently completed WWTP expansion project) and is not expected to have an adverse impact upon the traffic flow and pattern on these roads. The no-action alternative is not expected to impact traffic since no construction activities are proposed.

  Access to the outfall construction sites on the reef flat will be by rubber-tired or tracked vehicles from the staging area north of the WWTP. Construction materials, such as the outfall pipe, may be brought to the site by barge from another harbor, such as Honolulu Harbor. Material excavated from the reef flat for the proposed replacement outfall that is not used for backfill may be hauled to the staging area north of the WWTP or to Hickam Harbor for transfer to a barge for ocean disposal. It is estimated that the maximum frequency of round trips for this purpose would be approximately four trucks per hour. For the alignment on the northern portion of the reef flat, the route would be through the staging area adjacent to the WWTP and approximately 0.68 kilometers (km) (0.4 mile [mi]) on the paved road to the barge loading facility north of the WWTP. This route passes between the WWTP and the Fort Kamehameha housing area and circumvents the WWTP. If the optional barge loading facility located at Hickam Harbor is used, the route would be approximately 1.6 km (1 mi) on the paved road. This route would circumvent the Fort Kamehameha housing area and pass through industrical and vacant areas. For excavation on the southern portion of the reef flat, the route to the barge loading facility north of the WWTP would be across the reef flat to the unpaved access road between the Fort Kamehameha wetlands and the housing area. This route is approximately 1.1 km (0.7 mi) one-way on the paved road (see Figure 2.2-6). The route to the optional barge loading facility via the reef access corridor is approximately 0.64 km (0.4 mi) one-way on the paved road. Both routes are bordered by a combination of vacant and industrial areas. Based on the estimated vehicular frequencies, travel distances and routes, and the existing traffic densities, the impact of outfall construction activities upon traffic is not potentially significant.

- **Noise** - Outfall construction activities will not involve any exceptional noise-producing activities except for driving of piles for installation of the final section of the outfall pipe, including the diffuser section. Because pile-driving will occur approximately 2.7 km (1.7 mi) from the Fort Kamehameha housing area and 2.1 km (1.3 mi) from the Hickam Harbor recreational beach area, and because construction activities will be limited to hours between 7:00 a.m. and 7:00 p.m., the noise impacts are not potentially significant. Likewise, the construction activities for the underground injection alternative will be limited to hours from

7:00 a.m. to 7:00 p.m. to minimize noise impacts on the neighboring housing area. On the other hand, no action does not involve any construction, so noise impacts are not expected.

- **Hazardous waste disposal** - Construction of the outfall or the underground injection wells will not produce an exceptional quantity or type of hazardous wastes. Because all hazardous wastes generated will be handled and disposed according to current state and federal regulations, no potentially significant impacts will result from hazardous wastes produced by construction activities. No construction is proposed for the no-action alternative.

- **Seismic hazards** - The outfall and underground injection well design will comply with current seismic standards for Oahu, so the potential impacts related to seismic hazards are not significant. The no-action alternative does not propose the construction of new structures.

- **Flooding/tsunami inundation** - Because the outfall design does not include any above-ground structures, and because it will be designed to withstand storm-induced high water levels and waves, no potentially significant impacts will result from flooding or tsunami inundation. The design of the underground injection wells and associated above-ground structures will minimize flooding and/or tsunami impacts. No new structures are proposed as part of the no-action alternative.

- **Air navigation** - The flight-line air space of Honolulu International Airport's Reef Runway 8R is located in the vicinity of the proposed action and underground injection alternative. At the location where construction equipment for the proposed outfall or the underground injection alternative may be located under this flight-line air space, the bottom of the flight-line air space is at an elevation of 30 meter (m) (100 feet [ft]). Any equipment that extends approximately 30 m (100 ft) or more above mean sea level (msl) could interfere with air traffic. No obstructions penetrating the flight-line air space would be caused by the proposed action or alternatives. Any construction activity near an airport is subject to FAA requirements. Therefore, a Notice of Proposed Construction (permit number 7460-1) must be obtained from the FAA's Western Pacific Region prior to commencement of construction. The FAA would distribute a Notice to Airmen (NOTAM). Obstructions such as the tops of crane booms must be flagged and lighted.

4.3.3 Potentially Significant Issues

Sections 4.4 through 4.10 provide a detailed analysis of issues determined in Table 4.2-1 to be potentially significant. For each issue, the associated parameters for impact evaluation are identified. The impacts are then evaluated for potential significance relative to the existing environmental conditions. Cumulative impacts resulting from the proposed action or the underground injection or no-action alternatives, in combination with non-project-related activities, are also evaluated for significance. Mitigative actions that would be employed to eliminate or reduce the potential impacts are identified, and the significance of the mitigated impacts is evaluated.

4.4 Aquatic Environment and Marine Biota

This section evaluates construction, operations, and cumulative impacts on the aquatic environment resulting from the proposed action and the underground injection and no-action alternatives. The aquatic environment potentially affected includes the Class 2 Inland Waters of the Pearl Harbor Estuary, Class A Marine Waters, Class II Marine Bottoms, and the associated

aquatic ecosystem. The following discussion provides a summary of impacts and measures required to mitigate impacts on the aquatic environment.

The replacement outfall alternative is expected to have the following impacts on the aquatic environment:

- Construction impacts are mainly associated with sea-floor trenching and disposal of excavated materials. Identified temporary impacts are elevated turbidity surrounding the excavation area and minor physical alteration of the marine bottom. The outfall alignment has been carefully selected to minimize these impacts. These impacts will be further minimized by implementing BMPs during construction, such as proper silt containment and proper handling and disposal of excavated material.

- Operational impacts are primarily associated with relocation of the discharge and associated ZOM into Open Coastal Waters. Discharge into the Pearl Harbor Estuary will cease. This cessation may result in improved water quality in the immediate vicinity of the existing diffuser. The creation of a ZOM in Class A Open Coastal Waters delineates an area in which water quality standards may be exceeded. This is an unavoidable impact; however, as discussed in Section 2.2.3.1, the diffuser for the proposed action was selected to minimize the size of the ZOM. The increased nutrient levels around the proposed diffuser may attract fish and/or green sea turtles. Better effluent dilution provided by the replacement outfall is expected to yield a net improvement to the aquatic environment.

- Cumulative aquatic impacts are possible within Mamala Bay, which already receives discharges from the Honouliuli WWTP (HWWTP) and Sand Island WWTP (SIWWTP) outfalls. The proposed outfall, to be located in Open Coastal Waters, will increase nutrient levels above ambient levels at near-field[1] locations in Mamala Bay. (Nutrient levels at sites within and adjacent to the existing ZOM are expected to decrease as a result of the effluent discharge relocation.) Outside of the expected ZOM for the proposed outfall, the cumulative nutrient concentrations will continue to meet water quality standards for Class A Open Coastal Waters and, therefore, the cumulative impacts will not be significant.

The information required to determine if the underground injection would impact the aquatic environment and the extent of such an impact is presently unavailable. Installation of test wells and extensive, long-term testing and analysis would be required to evaluate potential impacts on the aquatic environment, the overall costs of which are prohibitive.

It is possible that the operation of the injection wells may affect the coastal environment by discharging through the caprock aquifer into the ocean. It cannot be determined from existing information regarding the specific geologic and hydrologic characteristics of the proposed injection area where and at what concentration the injected effluent would enter the ocean and whether environmental degradation would result.

The permeability of the calcareous caprock layers in the area is extremely variable, ranging from a small fraction of a meter per day (m/day) (3 feet per day [ft/day]) to over 6,000 m/day (20,000 ft/day). Because caprock aquifers on the east side of Pearl Harbor Entrance Channel have not been used for wastewater disposal and rarely used for irrigation supply, little is known about their hydraulic properties (see Appendix III). In addition, wastewater effluent injection wells on Maui have been suspected of contributing to high nutrient levels in coastal water, resulting in algal

[1]Near field refers to the area within which initial dilution occurs, where the plume is rising. Far field refers to areas beyond the initial dilution zone, where current transport is the major cause of additional dilution.

blooms; however, studies performed by DOH to verify these suspicions have thus far been inconclusive.[2]

The potentially significant impact of this alternative upon the aquatic environment cannot be determined because the concentration and location at which the injected effluent would enter the ocean is unknown. In this respect, the underground injection alternative may be similar to discharging effluent at an undetermined location without knowing the dilution that it would receive or the resulting impact upon the coastal waters. This potentially significant impact would be an inherent risk of implementing this alternative.

Because the no-action alternative allows for the continued discharge of treated effluent to Pearl Harbor Estuary, this alternative may adversely affect the water quality of the estuary if flow to the WWTP should increase within the capacity of the treatment plant. Even if the flow does not increase, the ability of the existing outfall to comply with permit conditions that may become more stringent in the future is questionable.

4.4.1 Methodology of Analysis

Impacts on the marine environment resulting from the construction and operation of the proposed action and alternatives have been analyzed in the following sequence:

- Identify waters or marine bottoms potentially affected,
- Establish the existing water quality,
- Survey and characterize the benthic environment,
- Use numerical models to project future water quality, and
- Compare projected impacts with the significance factors presented in Section 4.4.2.

The specific impacts analyzed by the above procedures include those resulting from:

- Construction effects,
- The existing ZOM,
- Replacement of the existing ZOM with the proposed ZOM, and
- The cumulative effect of the proposed outfall in conjunction with the existing HWWTP and SIWWTP outfalls.

4.4.1.1 Construction Impacts Methodology

Aspects of the marine environment that were evaluated for construction impacts were the benthic ecosystem, marine biota, and turbidity plumes. Impacts on the benthic ecosystem and marine biota were evaluated by comparing the extent of disturbance from proposed construction activities to the existing conditions in the marine environment. The turbidity and related suspended solids levels were assessed by the following methods (Appendix X):

- Review existing information on oceanographic and monitoring studies in the vicinity, specifically on relationships between suspended solids concentrations and turbidity levels and on turbidity levels from sea-floor excavation.
- Perform field investigations of currents and water circulation.
- Numerically model turbidity plume transport and dispersion.

[2]Verbal communication with Manager, Environmental Planning Office, State of Hawaii, Department of Health (February 1999).

The numerical turbidity plume model calculates plume dilution and transport and suspended solids concentrations within the plume. These calculations assumed that the plume centerline concentrations and the plume spread are affected by mixing and transport in a uniform current and by particle settling. Use of this model was based on the assumption that turbidity levels would correlate with concentrations of total suspended solids (TSS). Key model input parameters are initial plume concentration, plume depth, sediment grain size, and current speed. The plume study is provided in Appendix XI. The extent and duration of exposure to elevated turbidity at any one location are primary considerations of significance.

4.4.1.2 Operational Impacts Methodology

Pearl Harbor Estuary

The effect of eliminating the current sewage outfall from the Pearl Harbor Estuary has been evaluated using mass loading and water quality data obtained for the existing ZOM.

The Pearl Harbor Estuary receives pollutants from nonpoint sources and the existing outfall. Pollutant discharges from nonpoint sources are evaluated by the amount of sediment input (or mass loading). Pollutant quantities discharged from the existing outfall have been evaluated using water quality data from samples collected within the existing ZOM (Figure 4.4-1). As indicated previously, waters within a ZOM are permitted to exceed water quality standards.

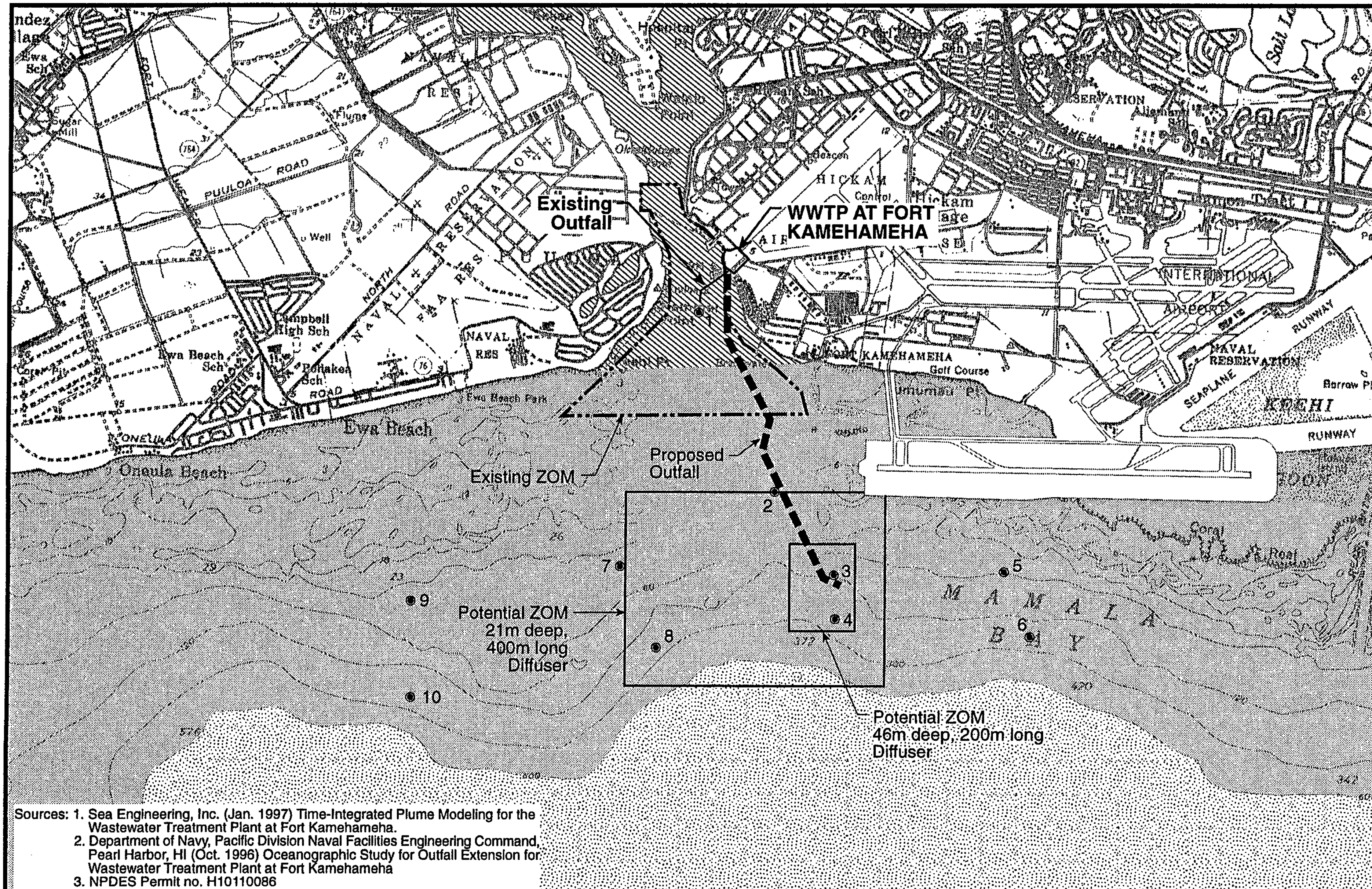
Class A Open Coastal Waters

Ambient water quality was evaluated using data collected bimonthly at stations centered near the proposed outfall diffuser location from February 1995 through February 1996. At each station, water was sampled at the surface, at mid-depth, and near the bottom (see Figure 4.4-1). The sampling locations cover the potential ZOM for the proposed outfall. Data at these locations provides an overview of existing water quality at the proposed outfall site, including the influence of Pearl Harbor water that naturally enters the ocean through the entrance channel and the present outfall discharge. For each depth at each station, geometric means of the data collected during this period have been used.

As presented in Appendix XI, time-integrated plume modeling was used to determine the near-field and far-field wastewater effluent plume behavior and resulting impacts. Near-field and far-field models were used to simulate the initial dilution of the effluent and subsequent transport and dilution of the plume within Mamala Bay. Plume modeling provided a basis for estimating the ZOM boundaries for the two diffuser configurations (see Figure 4.4-1). The actual ZOM will be established through the National Pollutant Discharge Elimination System (NPDES) permitting process. The model was used to plot dilution factors for the two diffuser configurations (see Appendix XI). These dilution factors, along with existing ambient water quality data, provide an estimate of the pollutant concentrations in the receiving waters. By comparing these projected concentrations with applicable water quality standards, the magnitude and extent of the water quality impact and the size of the ZOM for the proposed discharge was estimated.

The near-field model used for this analysis, called RSB (after its authors, Roberts, Snyder and Baumgartner), is the same model used by the Mamala Bay Study Commission for the Mamala Bay Study.[3] The near-field plume behavior depends on the following:

[3] P.J. Roberts (July 15, 1995) *Mamala Bay Study Plume Modeling, Project MB-4.*



Sources: 1. Sea Engineering, Inc. (Jan. 1997) Time-Integrated Plume Modeling for the Wastewater Treatment Plant at Fort Kamehameha.
2. Department of Navy, Pacific Division Naval Facilities Engineering Command, Pearl Harbor, HI (Oct. 1996) Oceanographic Study for Outfall Extension for Wastewater Treatment Plant at Fort Kamehameha
3. NPDES Permit no. H10110086

NORTH

0 2000 5000
SCALE IN FEET

0 400 800 2000m
SCALE IN METERS 1:60,000

LEGEND

- Class 2 – Inland Estuary
- Class A – Open Coastal Waters
- Class A – Oceanic Waters
- Water Quality Monitoring Stations
- ZOM Zone of Mixing
- 300 Depths in feet (1 foot = 0.305m)

Figure 4.4-1
ZONES OF MIXING AND WATER QUALITY MONITORING STATIONS
EIS for Outfall Replacement, WWTP at Fort Kamehameha
March 2001

- Effluent discharge volume,
- Length and depth of the diffuser,
- Prevailing currents, and
- Water column density stratification.

The model assumes that jet dynamics and plume buoyancy are the most important processes. It also assumes a linear density stratification and a uniform current throughout the water column. A mid-depth current velocity value, as measured at the project site by an acoustic doppler current profiler was used in the modeling.

The far-field plume behavior and movement depend on the ambient current since the plume is dispersed by oceanic forces. The far-field model simulated such a process. The model calculates the decrease in peak concentration for a continuous line source in a steady current. The ZOM for each diffuser configuration was estimated on the basis of both the near-field and far-field models.

4.4.1.3 Cumulative Impacts Methodology

In addition to the proposed relocated outfall for the WWTP at Fort Kamehameha, Mamala Bay receives treated wastewater effluent from the outfalls of two major municipal wastewater treatment plants: HWWTP and SIWWTP. Baseline water quality conditions across Mamala Bay were assessed using data collected during August and November of 1996 and January 1997. The three periods selected reflect seasonal variations in Mamala Bay and include both summer and winter seasons. In order to obtain a three-dimensional matrix of water quality constituents, five transects were established extending from near the shoreline to beyond the depth range of the diffusers (Figure 4.4-2). For each transect, sampling sites were established at locations where the water depth reached approximately 5 m (16 ft), 15 m (50 ft), 30 m (100 ft), 50 m (165 ft), and 80 m (260 ft). At each site, samples were collected at the surface, mid-depth, and near bottom. Water quality constituents measured were nutrients, chlorophyll a, temperature, pH, salinity, turbidity and silica content.

Water quality impacts were evaluated by estimating the constituent concentrations after the replacement outfall becomes operational. The concentration of a specific constituent at a given location was estimated based on the following:

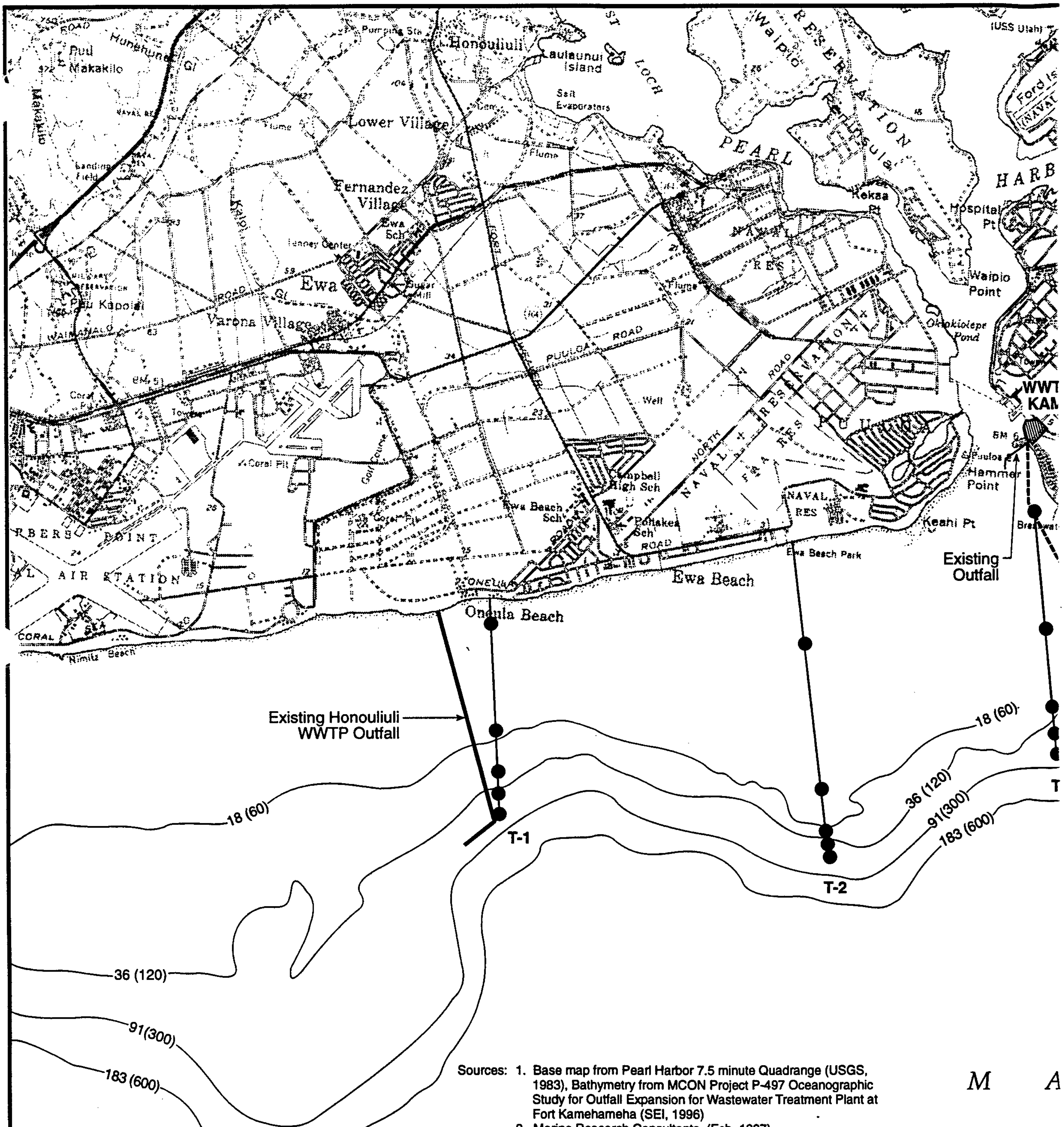
- Existing ambient concentration of the constituent,
- Existing concentration of the constituent in the effluent from the WWTP at Fort Kamehameha, and
- Projected dilution of the effluent at that location.[4]

The estimated concentration was then compared with the water quality standards for Class A Open Coastal Waters.

4.4.2 Significance Factors

Different sets of factors are used for evaluating the significance of water quality impacts during construction and operation. Unless noted otherwise, these factors do not apply to underground injection or no action.

[4]A three-dimensional model based on volumetric dilution was used to project the concentration at distant locations. Combining the input from the outfalls discharging to Mamala Bay and selecting the top layer (since the effluent plume is fresh water which is more buoyant than ocean water), the cumulative concentrations of pollutants at the points of overlap between effluent plumes from different WWTP outfalls were estimated.



Sources: 1. Base map from Pearl Harbor 7.5 minute Quadrange (USGS, 1983), Bathymetry from MCON Project P-497 Oceanographic Study for Outfall Expansion for Wastewater Treatment Plant at Fort Kamehameha (SEI, 1996)
2. Marine Research Consultants, (Feb. 1997)

NORTH

0 2000 5000
SCALE IN FEET

0 400 800 2000
SCALE IN METERS

1:60,000

LEGEND

● Far field Water Quality Sampling Locations

T-x Transects

(1)

Figure 4.4-2
FAR-FIELD WATER QUALITY SAMPLING LOCATIONS AND WWTP EFFLUENT OUTFALLS IN MAMALA BAY

EIS for Outfall Replacement, WWTP at Fort Kamehameha
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(2)

For outfall construction impacts, the factors considered in determining a significant impact on water quality include the extent or degree to which the implementation of an alternative would:

- Affect size and duration of the turbidity plume at any one point resulting from sea-floor excavation,
- Affect ability to meet specific turbidity standards for Class 2 and Class A waters, and
- Affect marine bottom and biota.

For operation of the proposed outfall, the factors considered in determining a significant impact on water quality include the extent or degree to which the implementation of an alternative would:

- Affect mass emission loading,
- Affect size of the estimated ZOM,
- Affect ability to meet water quality standards for Class 2 and Class A waters, and
- Affect marine biota.

Size and Duration of the Turbidity Plume. Construction of the proposed outfall will generate turbidity plumes near the areas of sea-floor excavation. The plume is defined as the area where turbidity standards for the specific class of waters is exceeded. The size and duration of the turbidity plume provide a measure of the impact of construction activities on water quality.

Extent of Marine Bottom and Biota Affected. The areal extent of the bottom habitat and biota affected by both construction and operation of the new outfall represents a measure of the impact on the marine benthic ecosystem. As specified in Hawaii Administrative Rules (HAR) Section 11-54-07e(3), "no action shall be pursued that would substantially risk, damage, impair, or alter the biological characteristics of reef flats or reef communities." In addition, coral reef ecosystems are protected under Executive Order 13089, *Coral Reef Protection*, as implemented by the Chief of Naval Operations' coral reef protection policy.[5]

Mass Emission Loading. Mass emission loading from outfall operation represents the mass of biodegradable organic matter and suspended solids discharged to the receiving waters per unit of time. It is a function of the concentrations of biochemical oxygen demand (BOD) and TSS in the effluent and the quantity of effluent discharged per unit time. BOD is a measure of respiratory use of dissolved oxygen, in milligrams per liter (mg/l), necessary for the decomposition of organic matter by microorganisms such as bacteria. The five-day biochemical oxygen demand (BOD_5) is the standard measure. TSS concentrations represent the nonfilterable solids in the wastewater effluent.[6] The mass emission loadings are the same for all three alternatives, but the discharge location, dilution, and degree of certainty vary among them.

Size of the ZOM. ZOMs are areas around outfalls that are exempt from water quality standards to allow for the initial dilution of treated effluent. Part I of the NPDES permit for the existing discharge from the WWTP at Fort Kamehameha states, "...within this zone (of mixing), the specific criteria listed in Section 11-54-05.2(d) of the State Water Quality Standards for the Pearl Harbor estuary may be exceeded." The ZOM boundary is established administratively through the NPDES permitting process for outfall operation. Only the proposed action and no action require ZOMs.

[5]Department of the Navy letter number 5090, ser N45D/80589139, dated December 4, 1998, from Chief of Naval Operations regarding Coral Reef Protection Policy.

[6]C.N. Sawyer and P.L. McCarthy (1978) *Chemistry of Environmental Engineering*, Third Edition.

Water Quality Standards. The existing NPDES permit for outfall operation requires waters outside the boundary of the ZOM to meet all specific criteria for either Pearl Harbor Estuary or Open Coastal Waters, as specified in HAR Sections 11-54-05.2(d) and 11-54-06(b)(3) and listed in Table 4.4-1. Of the various parameters listed, nitrate + nitrite nitrogen was determined to be the "critical" parameter, because it requires the greatest dilution (1,200:1) to meet DOH standards for open coastal waters.[7] Thus, wherever nitrate+nitrite nitrogen standards are met, all other parameters would meet water quality standards. The critical parameter is selected administratively as part of the ZOM boundary determination during the NPDES permitting process for outfall operation.

Table 4.4-1
Receiving Water Quality Criteria Applicable to the Proposed Project[8]

Parameter	Geometric mean not to exceed the given value		Not to exceed the given value more than 10 percent of the time*		Not to exceed the given value more than 2 percent of the time*	
	Class A (wet)**	Pearl Harbor Estuary	Class A (wet)	Pearl Harbor Estuary	Class A (wet)	Pearl Harbor Estuary
Total Nitrogen (μg N/l)	150.00	300.00	250.00	550.00	350.00	750.00
Ammonia Nitrogen (μg NH_4/l)	3.50	10.00	8.50	20.00	15.00	30.00
Nitrate + Nitrite Nitrogen (μg $[NO_3+NO_2]$/l)	5.00	15.00	14.00	40.00	25.00	70.00
Total Phosphorus (μg P/l)	20.00	60.00	40.00	130.00	60.00	200.00
Chlorophyll a (μg/l)	0.30	3.50	0.90	10.00	1.75	20.00
Turbidity (ntu)	0.50	4.00	1.25	8.00	2.00	15.00

* These standards were not used in this evaluation because the data obtained are not adequate for such analyses.
** Open Coastal Waters outside Pearl Harbor receive more than 7,060 m^3/day of fresh water discharge per shoreline kilometer (3 mgd of fresh water discharge per shoreline mile); thus "wet" criteria apply.
μg = microgram
ntu = nephelometric turbidity unit

4.4.3 Relevant Environmental Conditions

4.4.3.1 Existing Water Quality in Pearl Harbor Estuary

Table 4.4-2 provides mass emission loadings into Pearl Harbor Estuary from existing sources. As stated in Section 3.4, Pearl Harbor Estuary is a Water Quality Limited Segment (WQLS) that receives runoff from several freshwater streams. Discharges from these streams contribute land-based pollutants to the estuary, including sediments, nutrients, and other potentially toxic constituents. Pollutants from these land-based sources account for the majority of sediment and nutrient loading discharged to the estuary. The existing outfall accounts for only nine percent of

[7]SSFM Engineers, Inc. (October 1996) *Oceanographic Study for Outfall Extension for Wastewater Treatment Plant at Fort Kamehameha.* Prepared for U.S. Navy, Pacific Division, Naval Facilities Engineering Command.
[8]State of Hawaii, Department of Health (April 2000) *Hawaii Administrative Rules, Title 11, Chapter 54, Water Quality Standards.*

the total estimated water input and about one percent of the estimated solids input into the estuary.

Table 4.4-2
Relative Quantities of Liquids and Solids Input to Pearl Harbor Estuary from Existing Sources[9, 10, 11]

Input Source	Total Liquid Inflow	Suspended Solids and Sediment
	m^3/day (mgd)	metric tons/day (tons/day)
Existing Outfall	49,000* (13)	2.58** (2.84)
Other Land-based Sources	466,000 (123)	208.38*** (229.74)
Total	515,000 (136)	210.96 (232.69)

* Based upon existing WWTP design capacity, not existing flows.
** Data represents daily maximum TSS allowed by the existing NPDES permit.
*** Data represents total land-based sediment load to Pearl Harbor Estuary.

The existing NPDES permit for the WWTP at Fort Kamehameha identifies daily maximum limits, as well as monthly and weekly averages for BOD_5 and TSS. Discharge limits for other parameters such as settleable solids, oil and grease, pH, total residual chlorine, enterococci (an indicator of fecal pollution), and whole effluent toxicity have also been set. Although quarterly sampling and analysis for priority pollutants is required, effluent limitations for these parameters were not established. The bacterial indicator and whole effluent toxicity data are discussed in Section 4.8.

Table 4.4-3 summarizes the discharge limits for BOD_5 and TSS. Based on long-term monthly monitoring results, the effluent has been in general compliance with permit limits. Also, long-term receiving water quality monitoring has indicated that the existing discharge does not violate water quality standards or standards for criteria pollutants.

The water quality standards for Class 2 Inland Waters were met at Station 1, which is located within the existing ZOM near the existing WWTP outfall. Water chemistry analyses revealed that water exhibited reduced salinity and elevated levels of dissolved nutrients (including nitrate + nitrite nitrogen and phosphorus), turbidity, and chlorophyll, compared to the stations located in Open Coastal Waters (Appendix VI). The elevated levels can be attributed to the seaward flow of estuarine water from the inner lochs of Pearl Harbor and the wastewater effluent discharge. Concentrations of the critical parameter, nitrate + nitrite nitrogen, are presented in Table 4.4-4.

[9] State of Hawaii, Department of Health (February 28, 1990) *Fact Sheet for U.S. Navy Fort Kamehameha Wastewater Treatment Plant (WWTP) Reapplications for NPDES Permit and ZOM to Discharge to the Waters of the United States.*

[10] Belt Collins & Associates (August 1992) *Environmental Assessment of Expansion of the Wastewater Treatment Plant at Fort Kamehameha.* Prepared for Department of the Navy, Public Works Center.

[11] State of Hawaii, Department of Health (September 14, 1990) *Authorization to Discharge Under the National Pollutant Discharge Elimination System (Permit No. HI 0110086).*

Table 4.4-3
BOD_5 and TSS Limits of the Existing NPDES Permit [12]

Parameter	Monthly Average		Weekly Average		Daily Maximum	
	mg/l	metric tons/day (tons/day)	mg/l	metric tons/day (tons/day)	mg/l	metric tons/day (tons/day)
BOD_5	30	0.86 (0.95)	45	1.32 (1.46)	n/a	2.59 (2.86)
TSS	30	0.86 (0.95)	45	1.32 (1.46)	n/a	2.59 (2.86)

n/a = not available

Table 4.4-4
Nitrate + Nitrite Nitrogen Concentrations (in µg/l) Near the Existing and Proposed Outfall Locations*

Station**	Surface	Mid	Deep	Geometric Mean	DOH Standards***
1	5.58	8.73	2.57	5.00	15
2	7.40	2.59	2.30	3.53	5
3	1.83	0.65	0.71	0.78	5
4	0.86	0.52	1.04	0.77	5
5	1.51	0.70	1.51	1.17	5
6	0.65	0.50	1.05	0.70	5
7	3.92	1.23	1.46	1.91	5
8	1.34	0.61	0.81	0.88	5
9	2.69	0.68	1.11	1.27	5
10	0.85	0.66	0.92	0.80	5

* See Appendix VI. Concentrations at surface, mid and deep locations represent a geometric mean of seven samples collected from February 1995 to February 1996.
** Refer to Figure 4.4-1 for monitoring locations. Stations 2, 3, and 4 are near the proposed outfall. Others are far-field stations.
*** DOH Standards are based on the geometric mean.

4.4.3.2 Existing Water Quality in Open Coastal Waters

Nine sampling stations, identified as Stations 2 through 10, are located in Open Coastal Waters of Mamala Bay. Table 4.4-4 indicates that nitrate + nitrite nitrogen concentrations at these stations met the water quality standard for Open Coastal Waters during the one-year sampling period. Thus, as indicated in Section 4.4.2, all other parameters would have also met water quality standards.

[12]State of Hawaii, Department of Health (September 14, 1990).

4.4.3.3 Existing Marine Biota

The alternative outfall alignments traverse the benthic zones described in Section 3.5.3, impacting those zones to varying degrees depending on the specific route and the method of construction. Of the numerous potential routes and construction methods, the preferred route and construction method was selected to minimize potential impacts on the marine environment. The following paragraphs provide a more detailed description of marine biota in the zones traversed by this route, based on observations made during surveys conducted in August and September 1998. The purpose of these surveys was to obtain information on the benthic environment and to delineate high-density coral areas in the vicinity of potential alignments. Figure 4.4-3 illustrates the areas of high coral densities along the reef flat and channel wall with respect to the preferred alignment and construction methodology and shows the locations of reference stations as described in the following paragraphs. Refer to Appendix VIII, *Assessment of the Biotic Communities on the Proposed Alignments for the Fort Kamehameha Sewage Outfall Extension*, for a more detailed list of species density in these zones. Additional information regarding marine biota in the area is provided in Appendices VI, VII, and VIII.

Reef Flat (FK-1 to FK-3)

Shoreline Entry Location of Outfall Pipe to FK-1. Water depth in this interval is very shallow, generally less than 0.5 m (1.5 ft). Sand and rubble are the dominant substratum type in this area. The visually dominant species seen is the introduced algae, *Acanthophora spicifera,* attached to pieces of coralline rubble. Overall the algal cover of *Acanthophora* is between 15 to 20 percent. All of the fishes are species that are common in similar type habitats. None of the fish observed were abundant in the areas surveyed.

FK-1 to FK-2. The area from station FK-1 seaward for a distance of 70 m (230 ft) is similar to the previous interval. At approximately 70 m (230 ft) from FK-1, extending seaward, an array of living "microatolls" composed primarily of large single colonies of the stony coral *Porites compressa* (commonly called finger coral) occur. These microatolls are so named because they develop in the similar fashion as a true atoll. Single colonies grow in a circular mode laterally but are limited in upward growth by the shallow water depth at low tide. With time the living coral polyps are limited to the lateral vertical perimeters of the colonies while the centers of the colonies are bared limestone. The diameter of these microatolls ranges from approximately 1 to 5 m (3 to 16 ft). They become more common in a seaward direction (with increasing water depth). These microatolls are spaced from 5 to 20 m (16 to 66 ft) apart, separated by patches of white sand. One microatoll comprised of *Porites lobata* was seen in this area as were the corals *Pocillopora damicornis* and *Pocillopora meandrina*. The microatoll zone was relatively small in length along the outfall alignment (approximately 150 m [490 ft]). Within the microatoll zone, live coral cover was estimated at 15 to 20 percent of total bottom cover.

The dominant algal species in this area is *Acanthophora spicifera*; other algae seen include *Dictyosphaeria cavernosa, Microdictyon japonicum, Lyngbya majuscula, Padina thivyi, Sphacelaria furcigera,* and *Spyridia filamentosa*.

Invertebrates seen in this area include the ghost shrimp (*Callianassa variabilis*), crab (*Thalamita edwardsi*), featherduster worm (*Sabellastarte sanctijosehpi*), mantis shrimp (*Gonodactylus falcatus*), brittlestar (*Ophiocoma* sp.), and sea cucumber (*Holothuria atra).* In the sand are numerous small holes ranging from about 3 to 8 millimeters (0.01 to 0.31 inches) in diameter probably made by a number of cryptic burrowing polychaetes and crustaceans. These holes are spaced from 10 to 30 centimeters (cm) (4 to 12 inches) apart and are most evident where the

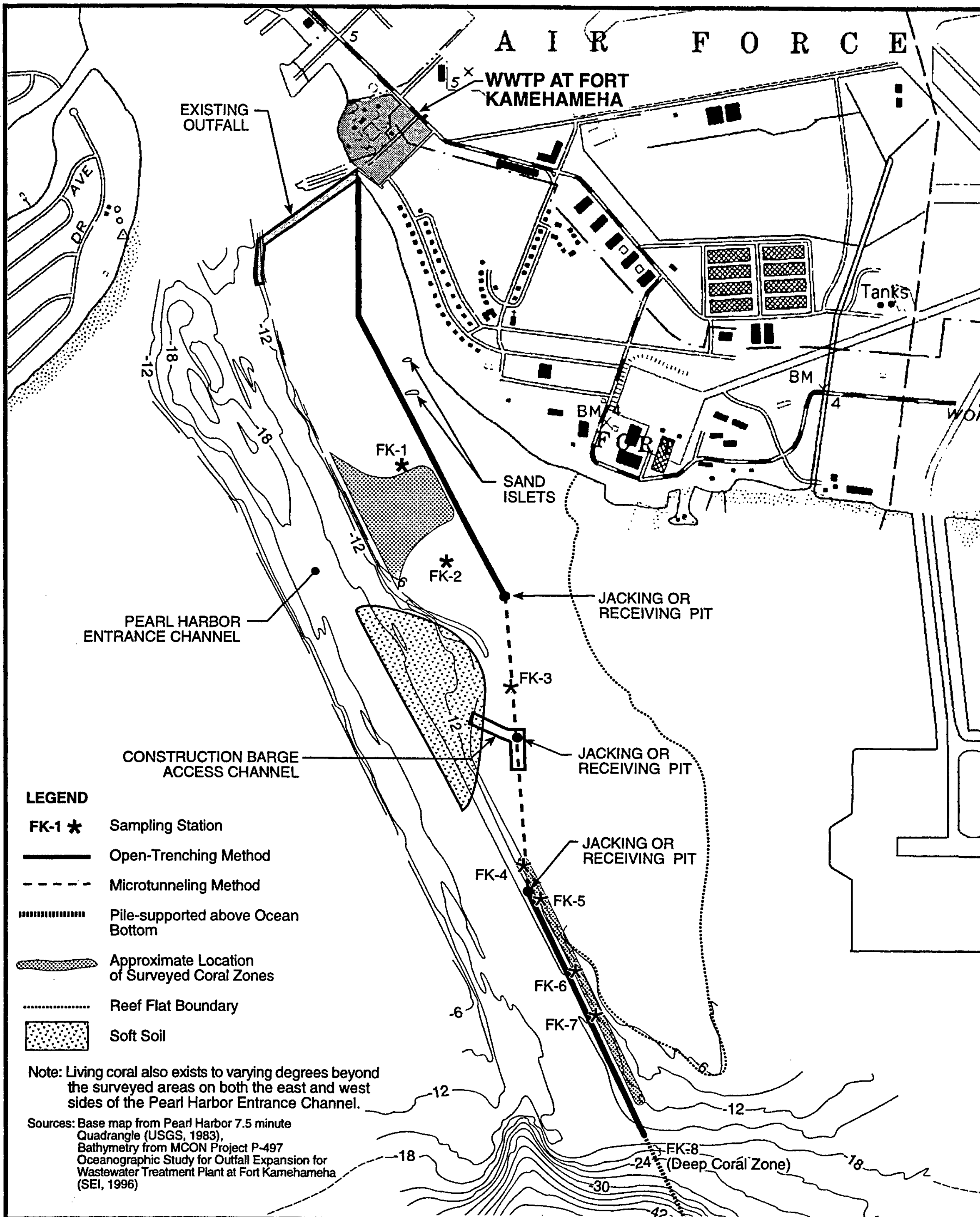

Figure 4.4-3
PREFERRED ALIGNMENT AND CORAL ZONES
EIS for Outfall Replacement, WWTP at Fort Kamehameha
March 2001

substratum is fine-grained sand. Most fishes seen in this area were juveniles, including *Thalassoma duperrey*, *Stethojulis balteata*, small parrotfish or uhu (*Scarus sordidus* and *Scarus psittacus*), convict surgeonfish or manini (*Acanthurus triostegus*), and ringtail surgeonfish or pualo (*Acanthurus blochii*). None of the fish species observed was abundant.

Seaward, the area of sand with microatolls is replaced by a mix of coralline rubble, sand, and emergent hard substratum. The hard substratum appears to be the remnants of large coral colonies that have died and are in a state of decay. These dead coral patches range in size from 1 to 3 m (3 to 10 ft) in diameter and are spaced from 1 to 8 m (3 to 25 ft) apart with sand and rubble in the intervening area. Much of the dead coral is overgrown by thick mats of *Dictyosphaeria cavernosa* (commonly called bubble algae); also present are the algae *Lyngbya majuscula* and *Acanthophora spicifera*.

Invertebrate species encountered here include the shrimp (*Saron marmoratus*), *Holothuria atra*, unidentified xanthid crabs (family Xanthidae), *Thalamita edwardsi, Gonodactylus falcatus, Ophiocoma* sp., and *Callianassa variabilis*. The same juvenile fish species were seen as previously mentioned. Occasionally, corals grow on elevated parts of the hard substratum; species seen include *Porites compressa, P. lobata, Pocillopora meandrina,* and *P. damicornis*. All corals occurring in this area are small in size (less than 20 cm [8 inches]) and uncommon. Total coral cover is less than 1 percent of bottom cover.

FK-2 to FK-3. Seaward of FK-2, the substratum continues as described above (i.e., hard substratum in the form of coral colony remnants with sand in the intervening areas). With distance seaward the sandy areas become larger and the dead coral heads less abundant.

Approximately 150 m (500 ft) seaward of FK-2, the algal-covered hard substratum changes to a mix of sand-covered hard (limestone) bottom and coralline rubble. On this substratum are scattered small coral colonies with total coverage of 1 to 2 percent. Species of coral include *Pocillopora meandrina, P. damicornis, Porites compressa,* and *Porites lobata*. Also present (in very small amounts) is the soft coral, *Palythoa tuberculosa*. Other exposed invertebrates present on the reef flat are the long spined urchin or wana (*Echinothrix diadema*), banded urchin (*Echinothrix calamaris*), green urchin (*Echinometra mathaei*), black urchins (*Tripneustes gratilla* and *Echinometra oblongata*), sea cucumber (*Holothuria atra*), and polychaete (*Loimia medusa*). The dominant algal species present is *Acanthophora spicifera*. This sand-rubble biotope with occasional small corals extends seaward to the area of the proposed jacking pit (FK-3).

Area of Proposed Microtunnel Intermediate Jacking/Receiving Pit (FK-3). Substratum at FK-3 is comprised of sand and rubble with patches of highly eroded limestone that appear to be the remnants of old coral colonies. These old coral colonies, while devoid of living coral, serve as habitat to a number of common reef species. Algae seen on the hard bottom (*Acanthoptera spicifera, Microdictyon japonicum,* and *Padina japonicum)* have a mean coverage of about 2 percent.

Station FK-3 is in the vicinity of the proposed jacking/receiving pit for the microtunneled portion of the outfall discharge pipe. Since there will be some removal of material and disturbance to the marine communities in the area, three 30 m (100 ft)-long transects were established to quantitatively ascertain the marine communities present in the area. These transects had an orientation parallel to the entrance channel. The first transect (A) was established 15 m (50 ft) east of buoy FK-3 with water depths ranging from 1 to 1.4 m (3 to 5 ft), the second (B) about 15 m (50 ft) west towards the entrance channel having water depths ranging from 1.2 to 2 m (4 to 7 ft), and the third transect (C) about 8 m (26 ft) west of the second transect (B) along the 3 to 4.5 m

(10 to 15 ft) isobath of the entrance channel edge. The observations along these transects are summarized below, either given as percent cover or counts of individuals for the entire transect line. A more detailed list of the species occurring in these transects is found in Appendix VIII.

- Transect A (Water Depth 1 to 1.4 m [3 to 5 ft]). Algae constituted approximately 1 percent of bottom cover with corals constituting approximately 2 percent. Five other species of invertebrates were observed in this transect, along with three species of fish comprised of 26 individuals.

- Transect B (Water Depth 1.2 to 2 m [4 to 7 ft]). In this transect, algae is less than 0.5 percent while coral constitutes 2.5 percent of the bottom. Seven species of other invertebrates were observed. Eight species of fish were observed, comprised of 37 individuals.

- Transect C (Water Depth 3 to 4.5 m [10 to 15 ft]). In this third and deepest transect, located approximately halfway down the channel cut slope, algae were absent. Corals comprised about 4.5 percent of the bottom. Five species of other invertebrates and 11 species of fish were observed. The fish included 51 individuals.

Transect C is situated in an area where pieces of limestone ranging in size from 1 m x 1 m to 2 m x 3 m (3 ft x 3 ft to 7 ft x 10 ft) are scattered over the sloping sand/rubble substratum. These limestone blocks serve as habitat for many of the fishes and invertebrates noted above.

Pearl Harbor Entrance Channel (FK-4 to FK-7)

General Considerations. The Pearl Harbor Entrance Channel has been dredged through old limestone reef. This limestone is a relatively continuous feature along the eastern side of the entrance channel to depths of about 20 m (65 ft). The dredging process left large individual blocks of limestone broken free of the limestone wall. These blocks are presently situated on the sand-talus slope that occurs between the vertical limestone wall and the sand-covered channel floor. The steep limestone "wall" varies in height from just 1.5 m (5 ft) to well over 5 m (16 ft) along the eastern channel edge.

The proposed outfall pipe would transition from the microtunnel into a trench along the channel edge that begins approximately at location FK-4. From this point seaward, the proposed pipe would be constructed in a trench and back-filled, following the eastern side of the entrance channel seaward.

In order to evaluate the potential impacts of the proposed alignment, surveys were conducted at four points along the channel wall (FK-4, 5, 6, 7). At all four sites, large pieces of limestone lie free of the wall on the talus slope. These limestone blocks range in size from about 1 m x 1 m up to 4 x 5 m (3 ft x 3 ft up to 13 ft x 16 ft). With distance seaward, the deep boundary of the limestone blocks increases: 11 m (36 ft) at FK-4, 12 m (40 ft) at FK-5, and 13 m (45 ft) at FK-6 and FK-7. The channel wall and limestone blocks provide habitat for fishes and invertebrates and, in some locations, provide resting sites for green sea turtles (*Chelonia mydas*). This area comprises a distinctive zone or biotope (the biotope of limestone blocks). In general, the development of marine communities is greater in the limestone block habitat at more seaward localities than at more shoreward sites. Below the depth of the blocks (i.e., down the channel slope) is a second distinctive biotope, the sand-talus slope biotope. The biota of each of these biotopes is described below.

The Limestone Block Biotope. The limestone block biotope is generally quite narrow and parallels the Pearl Harbor Entrance Channel. The width of this biotope ranges from about 5 to 35 m (15 to 115 ft); on the average, the width is about 15 m (50 ft). The relatively large amount of shelter afforded by these blocks has resulted in the development of a diverse fish community. In general, the algae are not well-represented in the limestone block biotope. This may be related to the number of grazing fish and invertebrates present. Algal species seen include *Acanthopthora spicifera, Porolithon onkodes, Sporolithon erythraeum,* and *Hydrolithon reinboldii.* Estimated coverage by these macrothalloid algae does not exceed 1.5 percent. Corals are abundant on the limestone blocks. Species of corals seen include *Porites lobata, P. compressa, Pocillopora meandrina, Pavona varians, P. duerdeni, Montipora verrucosa, M. patula, M. verrilli, Psammocora stellata, Fungia scutaria,* and *Leptastrea purpurea*. Over an area of 20 square meters (m^2) (215 square feet [ft^2)]), the measured coverage of living coral was 26 percent at FK-4, 22 percent at FK-5, 19 percent at FK-6, and 22 percent at FK-7. Sponges seen include the red sponge (*Spirastrella coccinea*), grey sponge (*Plakortis simplex*), and the black sponge (*Chondrosia chucalla*), but coverage by these species is less than one percent. Fishes are very common in the limestone block biotope. Rough estimates of biomass suggest that standing crops may locally be as high as 300 grams per square meter (g/m^2) (0.06 pounds per square foot [lb/ft^2]); standing crops in most natural reef areas do not usually exceed 200 to 250 g/m^2 (0.04 to 0.05 lb/ft^2). Species of fish and macroinvertebrates observed in this biotope are listed in Appendix VIII.

Green sea turtles are commonly encountered at several sites along the entrance channel where the limestone blocks are more concentrated, creating adequate resting habitat. At one approximate 10 m x 30 m (35 ft x 100 ft) area close to station FK-6, six turtles ranging from an estimated 45 to 80 cm (18 to 32 inches) in straight-line carapace length were seen in August 1998.

The Sand-Talus Slope Biotope. As noted above, a sand-talus slopes is sandwiched between the region of limestone blocks and the sand floor of the entrance channel. Like the limestone blocks, the sand-talus slope biotope is narrow and occurs along the eastern side through most of the outer channel (from FK-4 seaward). The width of this biotope varies from about 10 to 30 m (35 to 100 ft), and for much of it the substratum slopes towards the channel floor at a 3- to 10-degree slope. The major colonizer of the area is the seagrass, *Halophila ovalis,* present in patches covering from about 8 to 30 m^2 (90 to 325 ft^2) on the sand at depths from about 7 to 12 m (25 to 40 ft).

The biota of the sand-talus slope biotope is not well developed, with few diurnally exposed invertebrates or fishes present. The only invertebrate species seen include the auger shells (*Terebra inconstans* and *T. penicillata*), box crab (*Calappa calappa*), and a brown sea cucumber (*Bohadschia tenuissima*) in the sand. On the rubble and hard substratum are sponges *Microciona maunaloa, Spirostrella coccinea,* and *Chondrosia chucalla;* coverage by these species is low. Fishes are more common around the small amount of hard substratum present in this biotope. Because the biotope of limestone blocks is in very close proximity to the sand-talus slope biotope and many fishes inhabit that area, one often encounters individual fishes wandering out over the sand and rubble foraging for food. A more detailed list of fish species represented in this biotope is found in Appendix VIII.

Sand Rubble Zone (FK-8)

At the seaward terminus of the Pearl Harbor Entrance Channel, the bottom becomes a flat, gently sloping plain between the depths of 20 m (67 ft) and 23 m (77 ft). Bottom composition in this region, labeled FK-8, consists primarily of sand covered with limestone rubble fragments. Interspersed on the sand-rubble plain are small "patch reefs." The patch reefs are spaced

approximately 25 m (85 ft) apart and range in size from 1 to 3 m (3 to 10 ft) in diameter. Within each patch reef, living coral cover comprises 20 to 30 percent, with the remainder of the reef consisting of the limestone skeletal remains of coral colonies. These structures are not true "reefs" in that there is not an upward accreting solid limestone platform. Rather, these areas consist of denser aggregations of limestone rubble with a component of living corals. The dominant corals on these patch reefs are *Porites compressa, Porites lobata, Pocillopora meandrina,* and *Montipora verrucosa*. Growth forms of most of the corals on these parch reefs consist of flat encrustations and massive lobed colonies. Thus, while the patch reefs have a substantially higher vertical relief than the sand plain, there is not marked vertical relief of greater than approximately 25 to 50 cm (10 to 20 inches). Integrated over the entire sand/rubble plain, the patch reefs may comprise approximately five to 10 percent of bottom cover, while living coral cover is estimated at less than two to five percent of bottom cover.

These reefs provide habitat for a variety of reef fish, particularly butterflyfish *(Chaetodontidae)*, goatfish *(Mullidae)*, wrasses *(Labridae)*, damselfish *(Pomacentridae)*, surgeonfish *(Acanthuridae)*, and triggerfish *(Balistidae)*. Most of the fish observed in the survey were juveniles or small adults. Other dominant biota observed are the sea urchins *Heterocentrotus mammilatus, Echinometra mathei, Echinothrix diadema,* and *Tripneustes gratilla*. These urchins were common on both the sand-rubble bottom and on the limestone surfaces of the patch reefs. Fish communities observed in the area were similar in composition to the limestone block biotope described above.

The composition of the FK-8 area is typical of the depth range along the majority of the southern coastline of Oahu (Mamala Bay), as observed during other studies by the authors. Hence, it does not appear that the region of the proposed outfall alignment represents any unusual or unique habitats.

Deep Offshore Biotope (Sand Zone)

Beyond a depth of 23 m (77 ft) along the outfall alignment to a depth of 26 to 38 m (87 to 127 ft), bottom substratum consists of a plain of grey calcareous sand, as discussed above. Interspersed on the sand are blocks of limestone rubble. Surveys of the alignment revealed no coral cover in this area. Fish communities were also limited to lone individuals, presumably as a result of the lack of shelter in the area.

At the most seaward areas of the survey at approximately 36 m (120 ft), bottom composition consists almost entirely of gray sand. In many areas the sand exhibited ripple marks indicating resuspension and movements by currents. In other areas the sand surface was flat and covered with a greenish film, most likely consisting of benthic diatoms. Existence of benthic films suggests little movement of sediment by wave and current forces.

Summary of Marine Biota

Marine biota along the proposed outfall alignment are characterized by limited biodiversity and low abundance. Marine biota found in the vicinities of the shallow reef flat, the existing diffuser pipe, the entrance channel, and the offshore patch reefs, include the following (see Appendices VI, VII, and VIII):

- Sea cucumber (*Ophidesoma spectabilis*).
- Benthic algae, such as *Acanthophora specifera, Padina spp., Caulerpa spp., Enteromorpha sp.*
- Threatened green sea turtles.
- Reef corals such as *Porites Compressa* and *Pocillopora damicornis.*

- Juvenile and small adult reef fish such as butterflyfish, goatfish, wrasses, damselfish, surgeonfish, and triggerfish.
- A variety of sessile invertebrates, primarily sponges, alcyonarians, polychaete and sipunculid worms, and bivalve mollusks.

Other species, such as the Hawaiian monk seal (*Monachus schaurinslandi*) and humpback whale (*Megaptera novaeangliae*), are rarely found in the project area. Potential impacts of the proposed action, and the underground injection and no-action alternatives upon threatened and endangered species and coral are discussed in Section 4.6.

4.4.3.4 Existing Wastewater Discharges in Mamala Bay

The discharges of treated wastewater effluent into Mamala Bay from the existing SIWWTP, HWWTP, and the proposed WWTP at Fort Kamehameha outfalls were examined. Water chemistry data collected during 1996 indicated that effects of the SIWWTP and HWWTP outfalls were not apparent in the far-field (Appendix XII). Rainfall and subsequent discharge of runoff flowing out of the Pearl Harbor Entrance Channel appear to be the most important factors affecting ambient water quality in the offshore region.

Table 4.4-5 provides average nutrient levels of the effluent discharged from each of the WWTPs. Although nitrate + nitrite nitrogen is the critical parameter for estimating ZOM boundaries, its concentration in the effluent from SIWWTP and HWWTP is very low. Because these two facilities provide only primary treatment, the nitrogen in these effluents is predominately in the form of ammonia nitrogen. Since the WWTP at Fort Kamehameha treats the wastewater to an advanced secondary level, most of the ammonia nitrogen in the wastewater is oxidized to the nitrate + nitrite form of nitrogen.

Table 4.4-5
Nutrient Levels (in μg/l) and Flow Rate of Wastewater Effluent from Three Treatment Plants[13]

	SIWWTP	HWWTP	WWTP at Fort Kamehameha*
Ammonia Nitrogen	14,300	18,500	1,600
Nitrate + Nitrite Nitrogen	80	55	5,000
Total Nitrogen	19,000	24,100	8,200
Total Phosphorus	2,750	3,700	1,400
Flow Rate in m^3/day (mgd)	272,000 (72)	91,000 (24)	49,000 (13)

* Based on existing WWTP design flow.

Note: The flow rates indicated above represent the flow rates available at the time the modeling study was performed and differ from the flow rates currently on record.

[13] M. Stevenson and J. O'Connor (1996) "Pollutant Source Identification" in *Mamala Bay Study, Final Report*, Mamala Bay Study Commission; unpublished data provided by U.S. Navy.

4.4.3.5 Existing Ordnance

Based on historical information presented in Section 3.13, there is a potential to encounter ordnance along the proposed alignment. In October 1998, two objects suspected of being ordnance items were observed during a marine benthic survey. In March and April 1999, during a survey of the outfall alignment for ordnance items, one projectile was observed in the channel adjacent to the reef flat where water depths range from 7.6 to 17.1 m (26 to 56 ft) and five projectiles were observed at the diffuser end of the outfall. Although Navy Explosive Ordnance Disposal (EOD) personnel determined that all of the projectiles were safe to move and subsequently removed them from the site, there is potential for additional ordnance items to be encountered during the construction of the outfall. In the unlikely event that one or more ordnance items are detected within the established construction corridor that cannot be picked up and carried away (see Section 2.2.4.6), the Navy has decided that an engineering solution, involving minor outfall realignment to avoid disturbance of ordnance items, will be implemented. This engineering solution will not create additional impacts to the environment. Thus, the need for in-place detonation of ordnance is not anticipated and formal Section 7 consultation is not necessary. If it becomes apparent during project execution that in-place detonation of ordnance cannot be avoided, the Navy will reinitiate formal Section 7 consultation with National Marine Fisheries Service (NMFS) prior to continuing construction.

4.4.4 Construction Impacts and Mitigation

4.4.4.1 Replacement Outfall (Proposed Action)

Construction impacts on the marine environment are anticipated to be of two types. Construction activities such as trenching and hauling materials will directly impact the bottom and the sessile organisms dwelling within the construction corridor. Turbidity from unconfined construction activities will be generated and transported by currents through the water column. These two effects are analyzed below.

Direct Impacts of Proposed Construction Activities on Marine Biota

The marine environment is comprised of many elements, the major components of which are enumerated in Section 4.4.3. Potential construction impacts on the threatened green sea turtle are identified in Section 4.6.3.1. Potential construction impacts on living coral in the project area can best be minimized by avoiding locations which support coral growth. Although corals in the project area are generally sparse and poorly developed (less than 1 percent coverage for the majority of the route), areas of more substantial coral development occur at various locations (see Figure 4.4-3). The preferred alignment and construction methodologies have been selected to avoid open trenching in areas where coral coverage exceeds 5 percent. Composite coral coverage impacted by the construction corridor is less than 0.2 percent, or less than one fifth of 1 percent of the coral on the reef flat.

The preferred alignment was relocated about 100 m (325 ft) north of the proposed final alignment in order to avoid the area of microatolls in the vicinity of points FK-1 and FK-2 described in Section 4.4.3.3. In making this adjustment, the open trenched route encounters virtually no coral between the shoreline and the proposed microtunneling end pit. The microtunneled segments are designed to be 3.7 m (12 ft) or more beneath the bottom. These segments do not affect the benthic environment, except where the jacking and end pits are constructed. Only two microtunneling

legs are proposed, and the receiving pits will be in the bottoms of the adjoining trenched sections of the alignment.

The intermediate pit, located approximately 200 m (656 ft) south of station FK-3, and its associated construction barge access channel will impact a bottom area of about 130 m (426 ft) long by 20 m (66 ft) wide. Coral coverage in this area is approximately 2 percent, with cover up to 4.5 percent at the outermost extent on the channel wall. Without mitigation, coral loss of about 65 m^2 (700 ft^2) could be anticipated. Seaward from the intermediate jacking/receiving pit, the microtunneled route extends beneath the wall of the entrance channel and emerges into an open trench in the side of the entrance channel.

The preferred trenching alignment in the entrance channel has been located in the sand-talus slope zone to avoid impacting corals on the channel sides and remain outside the navigational channel. Along this route, the trench segment extends approximately 812 m (2,665 ft) to the seaward end of the dredged channel and effectively impacts no coral. Seaward of the channel dredging limits, in waters ranging from 17 m (55 ft) to about 23 m (75 ft) in depth, an area of small patch reefs occurs on the sand rubble bottom. Aggregate densities of coral in this area range between 2 to 5 percent of the bottom. This patch reef zone extends along the bottom approximately 100 m (330 ft). Trenching through this section would be expected to impact approximately 65 to 162 m^2 (700 to 1,750 ft^2) of coral. Impacts to living coral along the proposed alignment were discussed with the NMFS. A NMFS representative inspected the proposed alignment and concurred with the determination that corals will not be significantly impacted by the proposed action.[14]

In summary, impacts to coral have been minimized by careful selection of the outfall alignment and construction methodology.

Turbidity from Construction Activity

Construction of the new outfall will temporarily increase turbidity and suspended solids levels in the area surrounding active construction sites. Increased turbidity can be harmful to aquatic organisms by reducing the penetration of light needed by aquatic plants and by interfering with vision, feeding, and respiration of aquatic animals.

The extent of turbidity plumes predicted to result from construction activities at representative points without any mitigative measures are shown on Figure 4.4-4. Turbidity levels would exceed DOH standards within these plumes for the time that trenching and backfilling are occurring at the indicated location.

The extent of the turbidity plume on the reef flat and in the sandy zone would be small. The model predicted a larger turbidity plume from construction activities in the sand rubble zone and the entrance channel. For example, in the sand rubble zone, the plume could extend approximately 1,100 m (3,600 ft) to the west and 600 m (2,000 ft) to the east of the submarine excavation site (see Appendix X). The location of the turbidity plume would move as construction progresses. The total estimated duration of impacts would be approximately nine months on the reef flat, eight months in the entrance channel, five months in the sand rubble zone, and three months in the sand zone. The duration of turbidity generation at any specific location would be substantially shorter as the point of construction progresses along the alignment. The plume size on the reef flat would be minimized by the use of silt curtains. However, silt curtains would not be effective in deeper waters.

[14]Verbal communication with NMFS personnel (October 15, 1998).

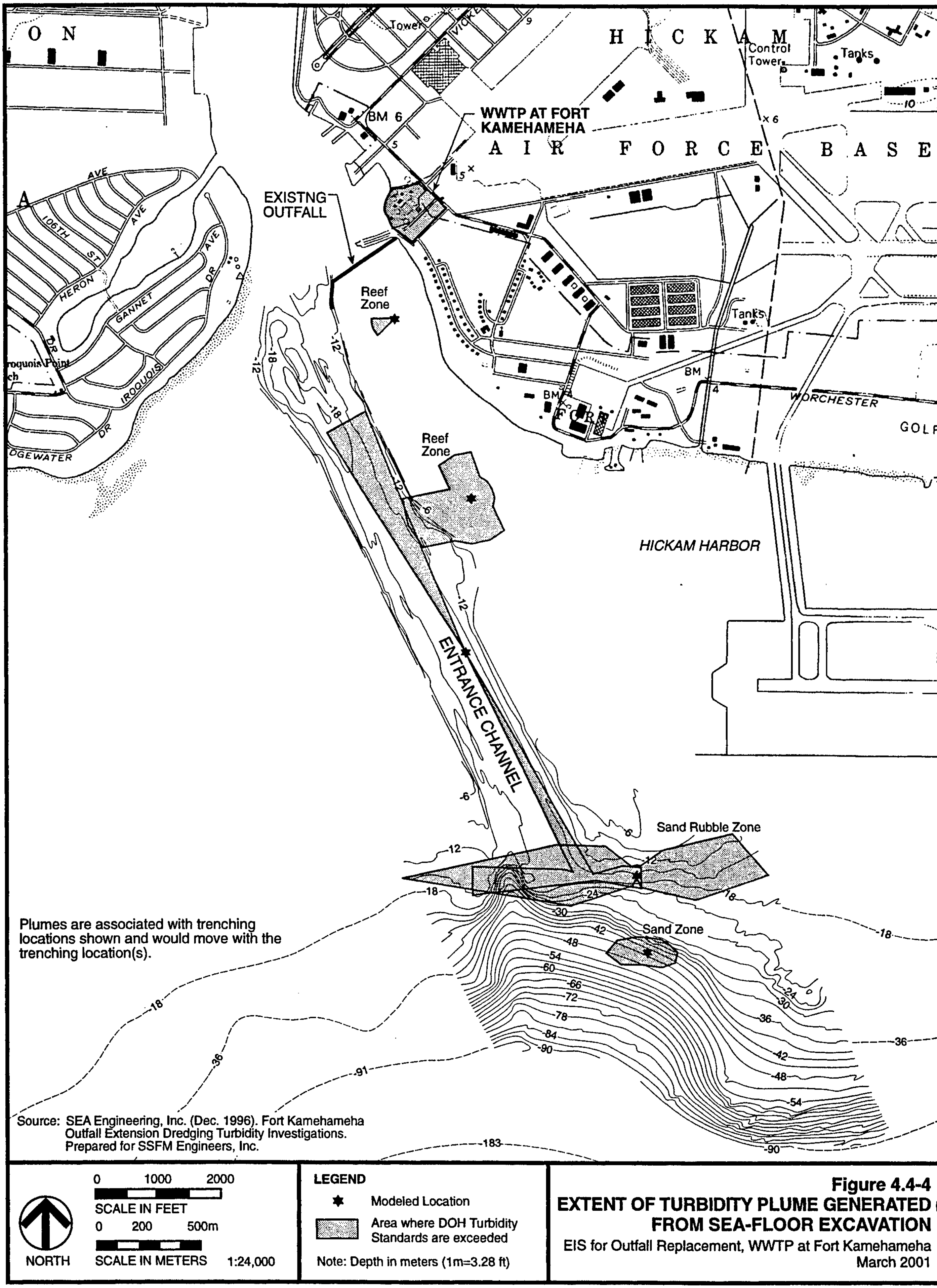

Figure 4.4-4
EXTENT OF TURBIDITY PLUME GENERATED FROM SEA-FLOOR EXCAVATION
EIS for Outfall Replacement, WWTP at Fort Kamehameha
March 2001

Turbidity plume generation would be intermittent during the construction period. Once construction activities cease, dispersion and settling would quickly reduce the suspended solids concentrated in the water column. The time required for turbidity to decrease to the DOH standard is estimated to be from one to seven hours (Table 4.4-6).

Table 4.4-6
Estimated Post-construction Time Required for Turbidity Levels to Meet DOH Standards*

Bottom Type	DOH Turbidity Standard (ntu)	Time after Construction Disturbance for Turbidity to Meet DOH Standard (hours)
Reef Flat	4.0** or 0.5***	1.5
Entrance Channel	0.5	7.0
Rock Zone	0.5	3.0
Sandy Area	0.5	1.0

* See Appendix X
** Class 2 Inland Water
*** Class A Open Coastal Waters
ntu = nephelometric turbidity units

Turbidity caused by construction in shallower waters, which tend to be relatively calm, will be contained by silt curtains in order to minimize transport of suspended sediment out of the construction area. Construction of the replacement outfall in deeper waters will take place in intervals of approximately 100 m (328 ft), which will reduce the total plume size and duration of time that any location within the affected area is exposed to elevated turbidity levels.

BMPs to reduce construction-related pollution impacts, such as hydraulic fluid or lubricant leaks or spills, on marine biota include the following:

- Equipment will be inspected daily for conditions that could cause spills and/or leaks and identified problems will be corrected before the equipment is used.
- Equipment will be cleaned to remove accumulated dirt, oil, and other materials before entering the nearshore area.
- No refueling, cleaning, or non-emergency maintenance of land-based equipment will occur in or near the water or on the shoreline.
- No chemical or petroleum product raw materials or wastes will be stored near the water.
- Silt curtains will be deployed around the work area in shallow and protected waters while construction activities are occurring and will be inspected and maintained at the beginning of each day.
- Spill response equipment will be kept on-site and will include at a minimum, booms to contain floating fuel or lubricants, absorbent pads, and containers for contaminated materials.
- In the event of a spill or leak in the water, the flotation cushion for the silt curtain will serve as a boom and provide secondary containment for the spill. Spill response equipment will form the primary containment.
- Construction activities will not proceed in an area if appropriate BMPs are not in place.

The weather will be monitored and the worksite and equipment secured if a storm is anticipated.

4.4.4.2 Underground Injection

Because the construction of underground injection wells would occur entirely on land, potential impacts on the aquatic environment would be limited. Implementation of standard BMPs, such as an erosion and sediment control plan, environmental protection plan, storm water pollution protection plan, and obtaining the necessary permits, would minimize potential impacts on the aquatic environment.

4.4.4.3 No Action

Construction activities are not proposed for the no-action alternative. Thus, this alternative would have no construction impacts on the aquatic environment.

4.4.5 Operational Impacts and Mitigation

4.4.5.1 Replacement Outfall (Proposed Action)

Pearl Harbor Estuary

The proposed outfall replacement will eliminate a point-source discharge of treated wastewater effluent from the Pearl Harbor Estuary. The current NPDES permit limits the BOD_5 and TSS loadings to this WQLS, as shown in Table 4.4-3. Relocation of the outfall will ensure future compliance with HAR Chapter 11-54, Section 03, which prohibits any increased discharge of wastewater pollutants into Pearl Harbor Estuary. It is not known whether the overall water quality of the estuary will significantly improve, because the dominant sources of pollution to the estuary are land-based sources originating from the watershed of Pearl Harbor (see Table 4.4-2).

The relocation will prevent anticipated regulatory nutrient limits from being exceeded, should the discharge flow increase (see Appendix I). Relocation of the outfall may decrease nutrient levels in the vicinity of the existing diffuser; however, changes in the estuary nutrient levels are not expected to be significant because the WWTP discharge contributes only a small fraction of the nutrients in the water column (see Appendix VI).

Open Coastal Waters

As shown on Figure 4.4-1, the estimated ZOM for the preferred 46-m (150-ft)-deep diffuser is smaller than both the ZOM for the 21-m (70-ft)-deep diffuser and the existing ZOM. The ZOM of the 46-m (150-ft)-deep diffuser is also small relative to the large area of Class A Open Coastal Waters in Mamala Bay, and the location of the ZOM has no unique properties or functions. The ZOM of the 46-m (150-ft)-deep diffuser will not have significant adverse impacts upon the Open Coastal Waters. Monitoring requirements will be developed in cooperation with the DOH Clean Water Branch during the discharge permit process under HAR Chapter 11-55.

The exact ZOM boundaries will not be established until an NPDES permit is issued for the new outfall. To evaluate the impacts of operations, the ZOM boundaries for the 46-m (150-ft)-deep diffuser were estimated. The ZOM boundaries were selected such that nutrient levels at the boundaries meet water quality standards for Class A Open Coastal Waters. These nutrient levels are presented in Table 4.4-7. Operation of the proposed outfall will not cause average nutrient levels to exceed Class A Water Quality Standards beyond the estimated ZOM.

Table 4.4-7
Nutrient Level Projections at the Boundaries of the Estimated ZOM[a]

Water Quality Parameter	Effluent Concentration[b] (µg/l)	Dilution Factor at ZOM Boundary[c]	Ambient Concentration Near the Diffuser[d] (µg/l)	Calculated Concentrations[e] (µg/l)	DOH Criteria (µg/l)
Nitrate + Nitrite Nitrogen	5,000	1,200:1	0.78	4.95	5.00
Ammonia Nitrogen	1,600	1,200:1	1.85	3.18	3.50
Total Nitrogen	8,200	1,200:1	94.20	101.03	150.00
Total Phosphorus	1,400	1,200:1	10.66	11.83	20.00

a See Appendix VI.
b Average concentrations from August 1995 through July 1996.
c Based upon required dilution for nitrate + nitrite nitrogen to meet water quality standards.
d Ambient concentration near the diffuser is based on the average concentrations for Stations 3, 4, 6 and 8, as shown in Figure 4.4-1. These stations were selected based upon similar locations and water depths to the proposed diffuser.
e Calculated concentration at the boundary of the estimated ZOM = (Concentration in wastewater effluent/Dilution factor) + Ambient concentration near the diffuser.

Because the mixing of the effluent discharge with ambient waters is relatively rapid, the region of mixing is small. Thus, only a small portion of the water column will have salinity and temperature characteristics that differ substantially from ambient conditions. Because the effluent plume will be generally warmer and less saline than the receiving waters, the plume will be buoyant and will rise following discharge. Based on the observations of other similar outfalls, such rising plumes have virtually no contact with the benthic surface.

Marine Biota

The increased nutrient levels within the ZOM in the immediate vicinity of the diffuser, and perhaps the diffuser structure itself, may attract reef fish and/or green sea turtles to this area, as occurs at the existing outfall. The relocation of this nutrient source is not expected to cause negative environmental impacts.

4.4.5.2 Underground Injection

The information required to determine if the underground injection would impact the aquatic environment and the extent of such an impact is presently unavailable. Installation of test wells and extensive, long-term testing and analysis would be required to evaluate potential impacts on the aquatic environment, the overall costs of which are prohibitive.

It is possible that the operation of the injection wells may affect the coastal environment by discharging through the caprock aquifer into the ocean. It cannot be determined from existing information regarding the specific geologic and hydrologic characteristics of the proposed injection area where and at what concentration the injected effluent would enter the ocean and whether environmental degradation would result.

The permeability of the calcareous caprock layers in the area is extremely variable, ranging from a small fraction of a meter per day (3.3 ft/day) to over 6,000 m/day (20,000 ft/day). Because

caprock aquifers on the east side of Pearl Harbor Entrance Channel have not been used for wastewater disposal and rarely used for irrigation supply, little is known about their hydraulic properties (see Appendix III). In addition, wastewater effluent injection wells on Maui have been suspected of contributing to high nutrient levels in coastal water, resulting in algal blooms; however, studies performed by DOH to verify these suspicions have thus far been inconclusive.[15]

The potentially significant impact of this alternative upon the aquatic environment cannot be determined, because the concentration and location at which the injected effluent would enter the ocean is unknown. In this respect, the underground injection alternative may be similar to discharging effluent at an undetermined location without knowing the dilution that it would receive or the resulting impact upon the coastal waters. This potentially significant impact would be an inherent risk of implementing this alternative.

4.4.5.3 No Action

Pearl Harbor Estuary

The no-action alternative is the continued discharge of treated effluent into the Pearl Harbor Estuary. As mentioned earlier, Pearl Harbor Estuary is classified as a WQLS, and an increase in point-source nutrient loadings, which may result from increased flow to the WWTP, will not be allowed. In addition, it is anticipated that NPDES permit conditions regarding discharges to Pearl Harbor Estuary will become more stringent in the future, requiring some type of action to reduce nutrient loadings or face violation penalties. The ability of the existing outfall to comply with these circumstances would be problematic, and continued use of the existing outfall would limit the ability of the WWTP to accommodate future flow increases.

Open Coastal Waters

As a result of the recent WWTP upgrade, it is not anticipated that increased discharges up to the plant capacity would cause a violation of water quality standards beyond the boundaries of the existing ZOM, which extends into Open Coastal Waters.

Marine Biota

Marine biota in the vicinity of the existing outfall have not been negatively impacted by the discharge of treated effluent. However, there is a potential for future increased effluent flows to have a detrimental effect on marine biota in the vicinity of the existing outfall.

4.4.6 Cumulative Impacts

4.4.6.1 Replacement Outfall (Proposed Action)

In addition to the proposed outfall, two existing municipal outfalls, from the SIWWTP and HWWTP, also discharge treated wastewater effluent into Mamala Bay. This section assesses the cumulative impacts of all three outfalls on Mamala Bay.

The plumes generated by the three outfalls exhibit different characteristics and seasonal variations, as detailed in Appendix XI. No summer season data are available for the HWWTP outfall.

[15]Verbal communication with Manager, Environmental Planning Office, State of Hawaii, Department of Health (February 1999).

Based upon available data, the least dilution (greatest pollutant concentration) resulting from intersecting dilution contours occurs between the proposed outfall and the existing SIWWTP outfall during winter.

Overlapping dilution factors for the three Mamala Bay outfalls are shown in Table 4.4-8 (see Appendix XI, Figures 12 through 15). The worst conditions result from overlapping of the 5,000:1 dilution plume from the 21-m (70-ft)-deep outfall option at Fort Kamehameha with the 10,000:1 dilution plume from the SIWWTP outfall during winter. The greater than 1,000,000:1 plume from the HWWTP would have a negligible effect on the cumulative concentration, so it has not been included in the calculations. Table 4.4-9 presents the resulting highest cumulative nutrient concentrations. The proposed 46-m (150-ft)-deep outfall would produce higher dilutions and lower cumulative nutrient levels than the 21-m (70-ft)-deep outfall. As shown, this worst case cumulative nutrient level at the point of maximum overlap would be an increase of up to 49 percent above the present ambient conditions but would still be a factor of three below DOH water quality criteria. Because nitrate + nitrite nitrogen is the critical parameter and nutrients in general are the effluent components highest in concentration relative to water quality standards, cumulative levels of all other parameters would also meet water quality standards at the point of maximum overlap. Thus, no significant cumulative impacts on water quality would result from the proposed action.

4.4.6.2 Underground Injection

The information required to estimate the potential cumulative effects of underground injection with other sources of contamination is presently unavailable. An investigation to determine the potential cumulative impacts upon the aquatic environment would be prohibitively expensive. It is possible that the operation of the injection wells may affect the coastal environment by discharging through the caprock aquifer into the ocean. As indicated in Section 4.4.5.2, the existing geologic and hydrologic information about the proposed injection area is insufficient to determine where and at what concentration the injected effluent would enter the ocean.

The potentially significant cumulative impact of this alternative upon the aquatic environment cannot be determined because the concentration and location at which the injected effluent would enter the ocean is unknown. This potentially significant impact would be an inherent risk of implementing this alternative.

4.4.6.3 No Action

Future increased flows to the WWTP could potentially cause increased nutrient/pollutant loadings to the estuary which may have detrimental effects on the aquatic environment in the vicinity of the existing outfall. These increased pollutant loadings could potentially have a cumulative impact on the estuary when coupled with runoff from nonpoint sources.

4.5 Socioeconomics

The purpose of this section is to describe ocean-related activities that take place in the project vicinity and how they may be affected by the proposed action and the underground injection and no-action alternatives. Commercial and personal consumptive activities in nearshore waters include fishing, seaweed gathering, and crab and lobster netting. Recreational activities include surfing, scuba diving, windsurfing, kayaking, and swimming in nearshore waters, and beach-combing at the Hickam Beach Park.

Table 4.4-8
Overlapping Dilution Factors for the Two Diffuser Options*

WWTP Outfall	Diffuser Depth = 46 m (150 ft) Diffuser Length = 200 m (656 ft)		Diffuser Depth = 21 m (70 ft) Diffuser Length = 400 m (1,310 ft)	
	Winter	Summer	Winter	Summer
WWTP at Fort Kamehameha	20,000:1	100,000:1	5,000:1	5,000:1
SIWWTP	10,000:1	50,000:1	10,000:1	1,000,000:1
HWWTP	>>1,000,000:1	n/a	>>1,000,000:1	n/a

* See Appendix XI.
n/a denotes not available.
Winter conditions are represented by data collected from January 24 through March 18, 1995, and October 27 through December 1, 1995. Summer conditions are represented by data collected from approximately March through October 1995.

Table 4.4-9
Cumulative Nutrient Levels (in μg/l) of Wastewater Effluent from Three Existing Treatment Plants*

Water Quality Parameter	Nutrient Input from		Ambient Conc. (C_{am})	Cumulative Conc. (C_c)	DOH Criteria (geometric mean)	Percent Increase Due to Outfalls**
	C_{si}	C_{fk}				
Ammonia Nitrogen	1.43	0.32	2.09	2.97	3.50	42
Nitrite + Nitrate Nitrogen	0.01	1.00	1.03	1.54	5.00	49
Total Nitrogen	1.90	1.64	95.36	97.13	150.00	2
Total Phosphorus	0.28	0.28	10.59	10.87	20.00	3

Notes:
C_{si} represents calculated concentration of 10,000:1 for the SIWWTP outfall plume.
C_{fk} represents calculated concentration of 5,000:1 for the 21-m-deep (70-ft-deep) outfall plume (diffuser option resulting in worst-case condition at Fort Kamehameha.
C_{am} represents the average of the observed concentration at Stations 3 through 10 (see Figure 4.4-1). Stations 1 and 2 were not used because they are located in Pearl Harbor Entrance Channel.
C_c represents calculated concentration for the point of maximum overlap; equals $C_{am} + [(C_{si}+C_{fk})/2]$
* See Appendix XI.
** Percent increase due to discharges from outfalls equals $(C_c - C_{am})/C_{am}$.
Contribution from the Honouliuli outfall is negligible (>>1,000,000:1 dilution) and therefore was omitted from these calculations.

4.5.1 Methodology of Analysis

The information in this section is summarized from an ocean activities study prepared for this project (see Appendix IX). Site visits and interviews with people familiar with Hickam Harbor, Fort Kamehameha, and neighboring shoreline areas were conducted during the fall of 1996. Interviewees included fishermen, lifeguards, longtime residents of this area, and representatives from the Hickam Harbor Outdoor Recreation Office, Hickam AFB Fire Station, and Honolulu Police Department. The study area included shoreline and offshore areas of the WWTP east to the vicinity of the Reef Runway.

4.5.2 Significance Factors

Two types of activities were assessed:

- Recreational activities: fishing, surfing, beach-combing, scuba diving, boating, shelling, and reef walking.
- Economic activities: personal consumptive and commercial fishing and limu gathering.

Factors considered in determining a significant socioeconomic impact include the extent or degree to which the implementation of an alternative would:

- Affect the livelihood of individuals who use the area,
- Affect activities unique to this locale that do not have reasonable alternatives elsewhere, and
- Affect activities of members of minority or disadvantaged populations.

The degree of significance can be ascertained by determining:

- Whether the activity is within the area influenced by the alternative,
- The number of users,
- The frequency of the activity, and
- Duration of the loss of use.

4.5.3 Relevant Environmental Conditions

Ocean activities occurring between the Reef Runway and the Pearl Harbor Entrance Channel are concentrated along the coast fronting the Hickam Outdoor Recreation Facility, Hickam Wetland Management Area, and Fort Kamehameha Housing (Figure 4.5-1). Most nearshore activity is concentrated at Hickam Beach Park, more than 1,200 m (3,900 ft) away from the construction zone. This beach park is open to military personnel and their dependents and guests. The beach is small and the water murky, but it is easily accessible. Offshore activity is concentrated at Ahua Reef, either on the flat or on the slope. Access to the reef flat is generally limited to military personnel.

The Department of Defense (DoD) has jurisdiction over the waters in the Pearl Harbor Entrance Channel out to the Reef Runway, therefore, civilian watercraft are not allowed inshore of the runway.

Activities within the study area are common to most coastal areas in Hawaii. These include fishing, trapping, kayaking, boating, reef walking, scuba diving, shelling, surfing, windsurfing, waterskiing, and thrill craft riding offshore.

Activities are conducted for economic purposes, personal consumption, and for pleasure. Some activities, such as fishing, can be both commercial and consumptive in nature.

4.5.3.1 Commercial Uses

The majority of fishing is done by commercial net fishermen from boats outside of the Pearl Harbor Estuary. They catch migrating schooling fish such as bigeye scad (*akule*) and jack (*ulua*).

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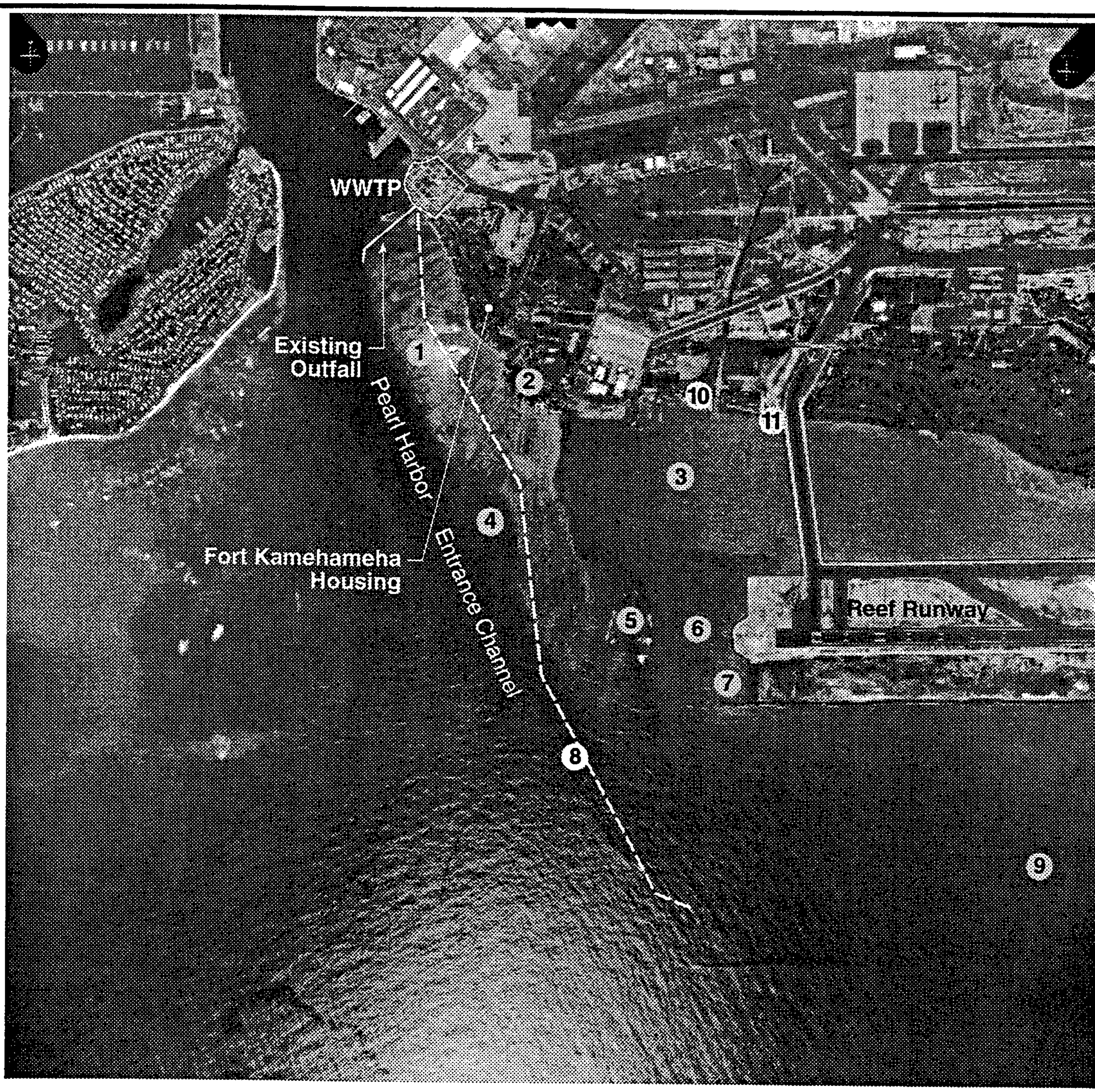


LEGEND

1. Reef Flat (Ahua Reef)
2. Hickam Wetland Management Area
3. Hickam Harbor
4. Channel "Wall"
5. *Seconds* Surf Site
6. *Firsts* Surf Site
7. Anchorage
8. Pearl Harbor Channel Entrance Buoy
9. Reef Runway Zone F
10. Hickam Beach Park
11. Honeymoon Beach

NORTH

0 1250 2500
SCALE IN FEET

0 200 500
SCALE IN METERS 1:30,000

Figure 4.5-1
OCEAN ACTIVITIES

EIS for Outfall Replacement , WWTP at Fort Kamehameha
March 2001

Large-scale fishing operations do not operate in the project area and are thus beyond the scope of this report.

Commercial Underwater Net Fishing. The more common type of fishing in this area is underwater net fishing. Fishermen use scuba gear and surround nets to herd reef fish in waters 15 to 30 m (50 to 100 ft) deep. The average frequency of users is three per day on weekdays and six per day on weekends.

Tropical Fish Collecting. Several commercial fish collectors operate in this area and sell their fish to aquarium fish wholesalers. Usually they scuba dive on the reef slope at depths of 10 to 20 m (33 to 66 ft). The number of fish collectors averages two per day on both weekdays and weekends.

Trapping. One commercial trap fisherman has operated in the area for the last 10 years and normally sets his traps 25 to 30 m (80 to 100 ft) deep. Trappers have gentlemen's agreements to stay out of each other's territories.

4.5.3.2 Personal Consumptive Uses

DoD personnel, their family members, and guests may fish recreationally in certain Navy-owned and Air Force-owned areas. In August 1998, DOH issued an advisory regarding the consumption of fish and shellfish from Pearl Harbor. The Navy and Air Force have posted signs along the shoreline of Pearl Harbor informing DoD personnel and the general public of this advisory.

Netting. Netting in the area is done for personal consumption. Species found nearshore are juvenile jacks (*papio*), threadfin (*moi*), bonefish (*oio*), milkfish (*awa*), mullet, bigeye scad (*akule*), and mackerel scad (*opelu*). Yellowstripe goatfish (*weke*), bigeye emperor (*mu*), bluestripe snapper (*ta'ape*), and white saddle goatfish (*kumu*) are found offshore on Ahua Reef. Octopus or "squid" are caught by fishermen in the offshore area. Some gill net fishing occurs on both sides of the Hickam Harbor Channel (see Figure 4.5-1, in vicinity of #5 and #6), and some throw-net fishing takes place on the Reef Runway revetment (see Figure 4.5-1, #7).

Crab Netting. This is both a commercial and personal consumptive activity, although nearshore waters are generally considered poor crabbing areas. Most crabbing within the study area occurs at the Reef Runway revetment area, which is noted for its large population of black rock (*a'ama*) crabs, a popular Hawaiian luau dish.

Gathering. During periods of calm seas, limpets (*opihi*) can be gathered on the seaward side of the Reef Runway on a limited basis and more frequently on the reef flat side of the Reef Runway. The number of users averages two per day on weekdays and four per day on weekends.

Pole Fishing. Pole fishing is prohibited along the shoreline. Beyond the shoreline, pole fishing occurs along the revetment that comprises the western edge of the Reef Runway and along the edge of the reef flat in Hickam Harbor (see Figure 4.5-1, #3). It can be either a personal consumptive or recreational activity. The number of users averages two per day on weekdays and four per day on weekends.

Handline Fishing. Commercial and personal consumptive handline fishing occurs at night at certain times of the year (see Figure 4.5-1, in the vicinity of #7), when as many as 20 boats may be found near the Pearl Harbor Entrance Channel. This is an infrequent activity and only occurs when fish are schooling.

Spear Fishing. Spear fishing for both commercial and consumptive use occurs in deeper waters near the Reef Runway at depths below 20 m (65 ft). Fish and octopus are caught at the outermost buoys in the channel (see Figure 4.5-1, in the vicinity of #8). Users average two per weekday and 15 per day on weekends.

Lobstering. Lobsters are gathered by hand, especially by divers near the outer channel markers. The number of users averages two per day on weekdays and ten per day on weekends and holidays. Lobster catching is a seasonal activity and is prohibited by the State of Hawaii during certain times of the year.

4.5.3.3 Recreational Uses

All personal consumptive activities described above may also be conducted for recreational purposes and, therefore, are not discussed in this section. Although the following recreational activities are conducted less frequently in the area of the proposed project than in more public, civilian beach areas, they do occur as follows:

Surfing. "Firsts" and "Seconds" are the primary surf breaks in the area (see Figure 4.5-1, #5 and #6). Approximately 800 m (2,600 ft) offshore, they are considered excellent intermediate and advanced surf sites. However, because they are some distance from the shore, they are infrequently used. The number of users averages 15 per day on weekdays and weekends. This is an intermittent seasonal activity occurring during good surf conditions in the summer months when larger ocean swells are experienced on the southern coasts of all of the islands.

Scuba Diving. A military dive club, the Sea Lancers, regularly dives offshore on both sides of the Pearl Harbor channel. The number of divers averages 50 per dive. Dives are limited to two per day on weekends and holidays.

Shelling. The reef flat is considered by some shell collectors as one of the last good shelling reefs on Oahu. This status is probably due to the fact that access is generally limited to military personnel. The number of users cannot be determined because it is a secondary activity, in conjunction with reef walking, gathering, and scuba diving.

Reef Walking. This is the most popular activity on the reef flat. Individuals and organized groups use the reef to observe such marine life as small moray eels, conger eels, and puffer fish. Users average two per day on weekdays and six per day on weekends and holidays. Guided walking tours are conducted six times a year and include up to 50 students per visit.

Kayaking. Ocean kayaking, using polyurethane kayaks, is a popular activity in Hickam Harbor (see Figure 4.5-1, #3). Some kayakers occasionally transit the project area while others remain close to shore.

Sailing. Small craft are occasionally sailed from the beach at Fort Kamehameha. Larger sailboats originate from Hickam Harbor. Boating activities in the harbor include sailing classes.

Outrigger Canoe Paddling. None of the Oahu canoe clubs trains in the area, however, they do transit the offshore waters near Fort Kamehameha.

Power Boating. Some recreational boaters use the cove inside the Reef Runway (see Figure 4.5-1, #7).The number of boats near the area is approximately one per weekday and three on weekends.

Thrill Craft. Jet skis operate offshore of the Reef Runway (see Figure 4.5-1, #9) and occasionally stray into Hickam Harbor, but are usually escorted away from the area by Hickam lifeguards.

Tour Boats. Commercial tour boats offer dinner cruises as well as various excursions. The Pearl Harbor cruise vessels traverse waters near the project area to enter and leave the harbor.

Waterskiing. Two primary waterskiing sites on Oahu are Hickam Harbor west of the Reef Runway (see Figure 4.5-1, #3) and Keehi Lagoon, east of the Reef Runway. Because Hawaiian waters offer few opportunities for waterskiing, these two sites are often used. The number of users averages one per day on weekdays and three per day on weekends.

Windsurfing. Depending on the prevailing wind direction, windsurfers launch at Hickam Harbor, at the east end of Hickam Beach Park (see Figure 4.5-1, #10), and at Honeymoon Beach. Windsurfers occasionally jump and surf waves at "Firsts" and "Seconds" but this is not encouraged by lifeguards due to the distance from shore. If in trouble, they may drift into the Pearl Harbor channel or into the Iroquois Point area before help could reach them. Windsurfers average three per day on weekdays and eight per day on weekends.

4.5.4 Construction Impacts

4.5.4.1 Replacement Outfall (Proposed Action)

The project area lies within restricted shore waters and is accessible primarily to DoD personnel. Construction will temporarily displace certain user groups, but the actual number of people affected will be small. Construction impacts may include suspending or limiting all ongoing ocean activities within the project area until the outfall is completed. Construction of the outfall and the diffuser should last approximately two years. The construction impacts are not anticipated to be significant because the total number of people affected will be small, the displacement of activities will be temporary, and most of the activities can be relocated during construction.

Some commercial and personal consumptive activities in the study area, including gill netting, crab netting, and pole fishing, will not be disrupted during construction because they occur at locations sufficiently remote from the construction zone. For commercial and personal consumptive activities, there are reasonable alternatives elsewhere. The Ewa shoreline, Waianae coastal area, and even urbanized sections of Oahu's south shore can easily be accessed for such activities as crab netting, handline fishing, and spear fishing. Any activity that occurs in the construction zone can relocate or simply avoid the zone during the construction period. The displacement of activities will be temporary. The total duration of construction should be approximately two years consisting of nine months on the reef flat, eight months in the entrance channel, five months in the rock zone, and three months in the sand zone. Construction on the reef flat may coincide with construction in deeper zones. After construction has been completed, displaced activities such as gill netting, gathering, and tropical fish colleting can resume within a short time.

For recreational activities, there are other sites suitable for scuba diving, windsurfing, and boating activities that transit the area. Because the surf breaks are at least 300 m (1,000 ft) from the construction corridor, construction activities will not disrupt surfing. Thrill craft and waterskiing are also conducted in the areas that will not be disrupted by construction activities. Tour boat operations will not be disrupted by construction activities. The most adversely affected group will be those participating in reef activities, such as shell collecting, and reef walking. These activities

will be temporarily displaced from the northern and western portions of the reef for approximately nine months during construction on the reef. During this period, access to the southeastern portion of the reef will be available for these activities. The number of recreational users temporarily displaced by this project will be small.

4.5.4.2 Underground Injection

As described in Section 2.3, the underground injection alternative requires construction of a well field, transmission pipelines, and additional facilities at the WWTP. These facilities would not be constructed in areas used for recreational or commercial activities, so construction of this alternative would not result in significant socioeconomic impacts.

4.5.4.3 No Action

The no-action alternative would not have construction impacts because construction activities are not proposed.

4.5.5 Operational Impacts

4.5.5.1 Replacement Outfall (Proposed Action)

The proposed action would not create a new source of effluent, rather it would relocate the existing discharge to a new locale at a deeper depth and provide better dilution. The treated effluent will meet all pathogen and toxin removal standards required by law (see Sections 4.4 and 4.8 for more details). Thus, the impact of the discharge of effluent from the WWTP at Fort Kamehameha on the area's water quality will be improved from its current level, and the potential impact of the discharge on users of the aquatic environment will be negligible.

The only ocean activities identified in the immediate vicinity of the proposed diffuser are spear and net fishing. Although there is no evidence that fish caught within the ZOM would pose a health risk to consumers, fishermen who may perceive the diffuser area as an undesirable place to fish will have the option of fishing at other suitable areas. No significant impacts on ocean activities are expected from the proposed discharge. It is not clear whether the removal of the discharge from waters bordering Ahua Reef will improve fishing or shelling conditions there, as the outfall represents only a fraction of the pollutant loadings at that location.

4.5.5.2 Underground Injection

The information required to determine if underground injection would impact ocean activities and the extent of such an impact is presently unavailable. Installation of test wells and extensive testing and analysis would be required to evaluate potential impacts on the aquatic environment where such activities occur. As indicated in Section 4.4, the overall costs of such a study would be prohibitive.

It is possible that the operation of the injection wells may affect activities in the coastal environment by discharging through the caprock aquifer into the ocean. It cannot be determined from existing information regarding the specific geologic and hydrologic characteristics of the proposed injection area where and at what concentration the injected effluent would enter the ocean and whether impacts on ocean activities would result. As indicated in Section 4.4, the

hydraulic properties of the caprock aquifer on the east side of the Pearl Harbor Entrance Channel are extremely variable and poorly defined.

The potentially significant impact of this alternative upon the socioeconomic activities in the aquatic environment cannot be determined because the concentration and location at which the injected effluent would enter the ocean is unknown. This potentially significant impact would be an inherent risk of implementing this alternative.

4.5.5.3 No Action

The no-action alternative would potentially have a significant impact on ocean activities if the volume of treated effluent discharged increases, affecting the water quality in the vicinity of the existing outfall, which is located near several reef activities (see Figure 4.5-1).

4.5.6 Cumulative Impacts

4.5.6.1 Replacement Outfall (Proposed Action)

No cumulative socioeconomic impacts are anticipated for the proposed action. The entire Pearl Harbor basin is heavily urbanized and not a pristine, undisturbed area. The water near the Pearl Harbor Entrance Channel contains urban runoff pollution from nearby businesses, homes, Honolulu International Airport, Hickam AFB, and the Pearl Harbor Naval Complex. Ships transit offshore waters. The proposed action would not diminish the existing environmental conditions, because the construction of a new outfall would not create a new effluent source. It merely relocates the existing discharge to a location within the same socioeconomic region of influence. The proposed action, combined with the effects of urbanization, the military installations, the airport, aircraft from the Reef Runway and transiting vessels, will not degrade the area's potential to support the socioeconomic activities identified herein.

4.5.6.2 Underground Injection

As indicated in Section 4.5.5.2, the information needed to assess the potential impacts of underground injection on ocean activities of the area is not available, and the cost of studies needed to acquire such information would be prohibitive. There is potential for treated effluent from underground injection to enter nearshore waters, such as the Pearl Harbor Estuary or Hickam Harbor. This additional pollutant source, in addition to surface runoff from nonpoint sources, could degrade water quality and cumulatively impact ocean activities by reducing the capacity of the area to support such activities. In particular, Hickam Harbor has limited water circulation, therefore, treated effluent entering the harbor would not readily disperse and dilution would be limited.

If, however, the treated effluent from the injection wells were to enter Open Coastal Waters, the cumulative impact of the HWWTP and SIWWTP outfalls and the underground injection effluent would probably be very small due to the greater amount of dilution occurring in Open Coastal Waters.

4.5.6.3 No Action

Since the existing outfall discharges into relatively shallow waters with limited circulation, there is potential for increased nutrient/pollutant loadings to the estuary and surface runoff from

nonpoint sources to cumulatively impact ocean activities occurring on the nearby reef. The estuary water quality could potentially deteriorate to such an extent as to displace some nearby ocean activities, both recreational and personal consumptive in nature, adversely impacting the participants.

4.5.7 Mitigation

4.5.7.1 Replacement Outfall (Proposed Action)

In addition to installing signs and construction ribbon at the site, the construction contractor will provide security for staging and reef construction areas for the protection of public health and safety. Security personnel will notify users of areas which are closed for construction purposes. Coordination with Hickam AFB Security Police will be implemented. Although not significant, socioeconomic impacts (temporary displacement of uses) resulting from construction of the replacement outfall are unavoidable. No mitigation measures are required for long-term operation of the outfall.

4.5.7.2 Underground Injection

Should nearshore water quality problems develop as a result of underground injection, mitigation may include upgrading the treatment plant to improve its capabilities, injecting into deeper strata, or relocating underground injection wells to an area where impacts to nearshore water quality are less likely.

4.5.7.3 No Action

No new actions are proposed; therefore, no mitigation is required.

4.5.8 Environmental Justice

Under Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, dated February 11, 1994, federal agencies are required to address the potential for disproportionately high and adverse environmental effects of their actions on minority and low-income populations. Specific requirements of these policies state that an agency shall ensure that:

- Programs and activities under its control or receiving federal funds, and that affect human health or the environment, do not directly or indirectly use criteria, methods, or practices that discriminate on the basis of race, color or national origin.

- Human health, economic, and social effects of its actions are analyzed, including effects on minority and low-income communities, as required under NEPA.

- Opportunities for community input in the NEPA process are provided, including identifying potential effects and mitigation in consultation with affected communities and ensuring accessibility to meetings, crucial documents, and notices.

- Mitigation measures outlined in an environmental assessment (EA), EIS, or Record of Decision, whenever feasible, address significant and adverse environmental effects of proposed federal actions on such communities.

- The public, including minority and low-income communities, has adequate access to public information relating to human health or environmental planning, regulation, and enforcement.

In compliance with Executive Order 12898, this document provides a demographic frame of reference for the area in which the WWTP at Fort Kamehameha is located. The proposed project is located adjacent to Hickam AFB and Naval Base Pearl Harbor with a total population of approximately 40,000 military personnel and their families. Military personnel and dependents are not considered to be minorities or low-income populations as contemplated by Executive Order 12898. No adverse health effects or risks have been identified that disproportionately impact any minority or low-income populations. Users who may be temporarily displaced during construction are not known to be members of a particular minority or low-income population group.

In accordance with NEPA, actions to ensure public notification of the proposed project are being conducted as part of the EIS process, and the public is provided the opportunity to participate and comment during the process.

4.6 Protected Species and Habitats

This section discusses impacts on flora and fauna, including listed (threatened and endangered) species, protected migratory shorebird species, and their habitats. Both marine and terrestrial habitats are evaluated.

For the replacement outfall alternative, major conclusions include the following:

- Terrestrial flora will not be affected by the proposed action because construction access and staging will occur only on land areas with urban scrub habitat.

- During construction, birds, including the endangered Hawaiian stilt (*Himantopus mexicanus knudseni*) and migratory shorebirds, may be temporarily displaced from foraging areas on the offshore islets and reef flats. However, given the relatively low numbers of individuals noted and availability of nearby similar undisturbed habitat, the degree of impacts to birds will not be significant. Mitigation of such impacts is discussed in Section 4.6.3.

- Areas of substantial coral development have been avoided by routing the outfall alignment around these areas or by microtunneling beneath them. Potential effects upon living corals from turbidity and subsequent sedimentation during outfall construction are not anticipated to be significant.

- Open trenching in the entrance channel will occur in proximity to foraging and resting habitat for green sea turtles situated along the channel sides approximately 50 m (165 ft) and more to the east. Since construction will occur at any one time in a relatively small length of approximately 100 to 150 m (330 to 500 ft) within at total one-kilometer (3,300-ft) length of channel, substantial areas will remain for foraging and resting.

- During operation of the outfall, marine life, particularly the threatened green sea turtles, may aggregate near the new diffuser. The effluent discharge will not adversely affect aquatic flora and fauna (see Appendix VI). No cumulative impacts on protected species are anticipated.

The construction and operation of the underground injection alternative would be in areas that are unlikely to provide habitats for listed species. However, site-specific surveys would need to

be conducted prior to any construction activity. In addition, much of the area proposed as the site for the injection wells is considered a jurisdictional wetland, and construction and operations would be subject to special requirements.

Impacts to protected species are not expected as a result of the no-action alternative. However, there is potential for operations to affect protected marine biota if flows to the WWTP were to increase in the future, increasing the nutrient and/or pollutant loadings to the estuary.

4.6.1 Significance Factors

Factors considered in determining a significant impact on floral and faunal resources include the extent or degree to which the implementation of an alternative would:

- Adversely impact species listed as endangered, threatened, or rare under federal or state law.
- Affect critical habitat required for the continued existence of endangered, threatened, or rare species.
- Affect essential habitat as designated in a U.S. Fish and Wildlife (USFWS) endangered species Recovery Plan.
- Affect jurisdictional wetlands.
- Affect the continued viability of coral reef ecosystem.
- Affect the distribution or population of species listed in the Western Pacific Regional Fishery Management Council's (WPRFMC's) Fishery Management Plan (FMP).

4.6.2 Relevant Environmental Conditions

4.6.2.1 Terrestrial Wildlife

The project area for the replacement outfall does not contain any special or unique habitats. A report summarizing bird survey results conducted in 1993, 1994, and 1996 is provided as Appendix V. Among those species observed (Table 4.6-1), the only listed species is the endangered Hawaiian stilt *(Himantopus mexicanus knudseni)*. Stilts rest on the offshore islets and forage in shallow waters. They would not be expected to nest on the offshore islets or the reef flats due to frequent human disturbance and easy access of the habitat to predators.

Previous wildlife surveys also identified the presence of introduced birds such as zebra dove (*Geopelia striata*), common myna (*Acridotheres tristis*), and red-vented bulbul (*Pycnonotus cafer*).[16] No listed mammal species were observed near the WWTP.

4.6.2.2 Aquatic Biota

The aquatic biota for the majority of the project area can be characterized as being of low biodiversity and low abundance. Only one federally listed species, the threatened green sea turtle (*Chelonia mydas*), frequents the proposed project area. The endangered humpback whale (*Megaptera novaeangliae*) is occasionally seen near the outermost portions of the project area, but usually remain farther offshore. One adult humpback and its calf were reported to have briefly entered Pearl Harbor within the last two years. Although the Hawaiian Islands Humpback Whale National Marine Sanctuary has been established in offshore areas north and south of Oahu, the closest sanctuary boundary to the project area extends from the shoreline at the Ala Wai Canal to

[16]P.L. Bruner (February 26, 1992) *Survey of the Avifauna and Feral Mammals for the Fort Kamehameha Wastewater Treatment Plant Expansion Project, Hickam Air Force Base, Oahu.* Prepared for Belt Collins & Associates.

Table 4.6-1
Summary of Birds Observed on Nine Surveys Conducted between 1993 and 1996*

Category	Common Name	Scientific Name	Total No.
Migratory shorebirds	Pacific golden plover	*Pluvialis fulva*	39
	Ruddy turnstone	*Arenaria interpres*	19
	Sanderling	*Calidris alba*	9
	Wandering tattler	*Heteroscelus incanus*	8
Resident wetland birds	Hawaiian stilt	*Himantopus mexicanus*	2
	Black-crowned night heron	*Nycticorax nycticorax*	3
Seabirds	Brown booby	*Sula leucogaster*	1
	Common (brown) noddy	*Anous stolidus*	10

*See Appendix V.

the 183-m (600-ft or 100-fathom) isobath (not including the Ala Wai Small Boat Basin), approximately 8.9 km (5.6 mi) away from the project site.[17]

Ocean and reef areas in the vicinity of the project are known to be used by green sea turtles for foraging and resting. This includes the entire channel area, the adjoining reef, and the environmentally preferred construction corridor. As discussed in Section 4.4.3.3, turtles have been observed throughout the heavily used channel, the channel edge and limestone block biotope, and eastward across the outer and middle portions of the reef. Turtles in this area appear habituated to the presence of human activities on and in the water.

Under Section 7 of the Endangered Species Act, the USFWS, NMFS, or both agencies, must be consulted when a proposed action may affect listed species or result in the destruction or adverse modification of critical habitat designated for such species. Informal Section 7 consultations with USFWS and NMFS were initially completed in 1997. Both agencies concurred that construction and operation of the proposed outfall are not likely to adversely impact any listed species or designated critical habitat (see Appendix II-m). Subsequently, new information on the potential to encounter military ordnance in the construction corridor and the potential need for disposal of ordnance items by in-water detonation, which could have adversely affected green sea turtles in the area, caused the Navy to initiate a formal Section 7 consultation with the NMFS. However, the Navy has decided that an engineering solution, involving minor outfall realignment to avoid disturbance of ordnance items, will be implemented, in the unlikely event that one or more ordnance items are detected within the established construction corridor that cannot be picked up and carried away. This engineering solution will not create additional impacts to the environment. Thus, the need for in-place detonation of ordnance is not anticipated and formal Section 7 consultation is not necessary. If it becomes apparent during project execution that in-place detonation of ordnance cannot be avoided, the Navy will reinitiate formal Section 7 consultation with NMFS prior to continuing construction.

[17]U.S. Department of Commerce, National Ocean Service, National Oceanic and Atmospheric Administration, Office of Ocean and Coastal Resource Management, Sanctuaries and Reserves Division and State of Hawaii, Department of Business Economic Development and Tourism (February 1997) *Hawaiian Islands Humpback Whale National Marine Sanctuary Final Environmental Impact Statement/Management Plan.*

The construction corridor crosses an inshore reef flat, then transitions into a dredged channel, and follows the channel until it descends the natural reef slope seaward of the dredged channel limits, to end in a sandy zone. Live corals occur at varying densities and in various assemblages in the project area, but the preferred alignment has been selected and configured to avoid the areas of appreciable coral density. Two relatively large communities of living coral were located along the preferred alignment. These live reef-building corals are estimated to cover about 2 percent of the seabed in these areas. These coral areas extend for distances of 75 m (245 ft) and 100 m (330 ft), respectively, along the construction corridor. The first of these coral communities is located in the vicinity of the intermediate microtunnel jacking/receiving pit and construction barge access channel. The second is located seaward of the dredged navigation channel, on the rubble slope at depths of 17 to 23 m (55 to 75 ft).

4.6.2.3 Essential Fish Habitat

The WPRFMC has amended four FMPs to include Essential Fish Habitats (EFH) and Habitat Areas of Particular Concern (HAPC). These amendments and FMPs are:

1. Amendment 6 to the Bottomfish and Seamount Groundfish FMP,
2. Amendment 8 to the Pelagic FMP,
3. Amendment 10 to the Crustaceans FMP, and
4. Amendment 4 to the Precious Corals FMP.

The Navy met with NMFS to discuss whether and how the proposed project could affect the EFHs and HAPCs designated in these FMPs. NMFS expressed concern only on the HAPC for bottomfish, mainly in the vicinity of the proposed diffuser segment.

After considering results of direct underwater observations, reviewing the available geotechnical data, and viewing underwater videotapes of the proposed outfall alignment, NMFS stated in a letter to the Navy dated November 19, 1999, that:

> *The proposed project design includes adequate measures to insure minimal impacts to EFH for species managed under these FMPs. These measures include minimizing impacts from open trench areas by avoiding live coral habitat, the use of microtunneling to further avoid impacts to habitat, the use of pile supports for the distal portion (diffuser section) of the outfall alignment. Based on the information obtained during reconnaissance dives at the diffuser site, it appears unlikely that the installation of the diffuser will adversely impact the HAPC for bottomfish.*
>
> *An additional EFH assessment may be required once the final Environmental Impact Statement is completed and the preferred alignment is selected. This assessment should be prepared by the Corps of Engineers during the Department of the Army permit process. At that time, further EFH Conservation Recommendations may be necessary.*

Correspondence pertinent to the EFH consultation is provided in Appendix II-m.

4.6.2.4 Wetlands

The Hickam Wetland Management Area is located on the Hickam AFB shoreline between Hickam Harbor and the Fort Kamehameha housing. This area is home to obligate wetland vegetation, such as red mangrove trees (*Rhizophora mangle*) and pickleweed (*Batis maritima*). The same vegetation

is also found lining the banks of the drainage channels along the northern and southeastern boundaries of the WWTP.

4.6.3 Construction Impacts and Mitigation

4.6.3.1 Replacement Outfall (Proposed Action)

Construction on the reef flats would temporarily displace the birds and marine life that inhabit, transit, or visit the area. Given the relatively low abundance and poor diversity noted and the availability of similar undisturbed habitat nearby, the degree of impacts to protected birds and aquatic life would be minimal. Mitigation will include cleaning up debris in the construction areas and restoring the disturbed area to match existing environmental conditions, to the extent feasible.

Green sea turtles would not be impacted significantly by normal construction activities associated with the proposed action. It is estimated that construction will be accomplished in work increments of approximately 150-m (500-ft) sections, which should allow sea turtles to forage and rest at will. In addition, turtles in the construction area would not be at direct risk from slow moving construction vessels.

Because green sea turtles and other listed species could conceivably enter the project site, the Navy will implement procedures to eliminate or minimize adverse impacts to threatened and endangered species during all activities associated with outfall construction. If a listed species is observed entering an active construction site, construction activities will cease and resume only after the animal voluntarily departs from the active construction site. The Pacific Islands Area Office Protected Species Program will be notified of each such incidence.

Federal policy for coral reef protection, as implemented by the Chief of Naval Operations' coral reef protection policy,[18] requires that proper consideration be given to coral reef protection during environmental review of Department of the Navy actions. Of the outfall replacement effluent disposal options evaluated, the preferred alignment and construction methodology results in the least impacts on living coral. Based on the analysis summarized in Section 4.4.4, up to 65 m^2 (700 ft^2) of coral could be affected in the area of the proposed intermediate jacking/receiving pit and barge access channel. From 65 to 162 m^2 (700 to 1,750 ft^2) of coral could be affected by construction on the offshore rubble slope. The use of the jacking pit enables microtunneling to be employed during construction, which avoids surface disturbance in the shallow to intermediate depth zone of the reef for a distance of about 850 m (2,800 ft). Most of the coral within the project area is in this zone. Microtunneling effectively eliminates impacting corals in this area. Coral development in the off-shore rubble zone is extremely sparse. Overall, the aggregate coral coverage impacted by the outfall along its entire length is less than 0.2 percent, or less than one fifth of one percent of the construction corridor.

The proposed outfall alignment has been designed to minimize damage to coral by avoiding construction in areas of substantial coral growth. On the reef flat, turbidity will be contained within the construction corridor by the use of silt curtains. For the microtunneling portion of the alignment, turbidity will only be generated during excavation and backfill of the jacking and receiving pits. Silt curtains will be used to contain turbidity at these locations.

In the Pearl Harbor Entrance Channel, water depths are such that silt curtains would be ineffective for that portion of the alignment. Modeled distribution of turbidity indicates that areas with coral

[18]Department of the Navy letter number 5090, ser N45D/80589139, dated December 4, 1998, from Chief of Naval Operations regarding Coral Reef Protection Policy.

colonies would be within the turbidity plume along this portion of the alignment. Significant impacts would occur to corals if prolonged turbidity caused mortality to symbiotic photosynthetic algae, or if smothering of the coral organism occurred from resulting sedimentation. Because the materials to be excavated along the alignment are primarily of sand size and larger and settle quickly, burial of coral heads outside of the construction corridor is not anticipated. Strong currents and waves are common in the project area and will tend to sweep debris off of the corals. Construction will be limited to a specific reach of a few hundred meters at a time in which actual excavation will be of short duration; hence, the period in which any area of coral would be exposed to turbidity is also short. Therefore, a prolonged reduction in water clarity is not expected, and living corals will not be significantly affected.

In general, the impact of turbidity and sedimentation upon living corals in the vicinity of the construction activities will be minimized by the proposed alignment and the use of silt curtains on the reef flat. In the deeper portions of the alignment located in Open Coastal Waters, circulation from natural currents are expected to prevent construction turbidity and sedimentation from significantly impacting adjacent living corals. Appendix VII provides a discussion of construction impacts to corals based upon past experience in Hawaii.

The potential impact upon living corals caused by barge mooring lines during construction in the Pearl Harbor Entrance Channel will be mitigated by requiring the construction contractor to propose a mooring system that will not damage living corals on the reef flat, and to receive Navy approval of the plan with respect to coral protection prior to construction.

Additional construction mitigation measures include:

- The preferred alternative has been designed to minimize impacts to corals and the coral reef ecosystem by avoiding construction in areas of substantial coral development.

- Mitigation during construction will include the use of silt curtains in all areas of excavation on the reef. All construction equipment will be inspected, cleaned, and maintained daily to prevent hydraulic fluid, grease, and oil from being released into the water. Refueling of land based vehicles will only be performed on shore. All petroleum, oil, and lubricant products will be stored and dispensed in areas that do not risk release into the water should an accidental discharge occur. Appropriate secondary containment will be provided for petroleum products and any potentially harmful hazardous substances. The contractor will be required to develop an emergency response plan for containing the release of petroleum products and to maintain adequate response equipment on hand to meet the most likely worst case spill scenario.

- No staging of excavated material ashore will be allowed except at the designated site adjacent to the WWTP. Drilling mud (bentonite clay slurry, a non-hazardous natural product) will be separated from the excavated material for reuse, prior to disposal.

Executive Order 13186, *Responsibilities of Federal Agencies to Protect Migratory Birds*, requires federal agencies taking actions that have, or are likely to have, a measurable negative effect on migratory bird populations to develop and implement a Memorandum of Understanding with the USFWS that promotes the conservation of migratory bird populations. Construction activities for the proposed action have the potential to impact migratory birds that frequent the project area. The outfall alignment has been designed to avoid areas where migratory birds are known to rest and forage. Thus, construction activities are not expected to have a measurable negative effect on migratory bird populations.

Executive Order 11990, *Protection of Wetlands*, directs federal agencies to avoid long-term and short-term adverse impacts associated with the destruction or modification of wetlands, and to avoid direct or indirect support of new construction in wetlands. Construction activities have the potential to damage wetland areas. Construction staging areas (see Figure 2.2-5) have been delineated to avoid areas designated as jurisdictional wetlands.[20] Construction staging activities will have no significant impact upon protected species.

4.6.3.2 Underground Injection

The areas proposed for the underground injection alternative were not studied in terms of flora and fauna for this project. However, floral and faunal surveys were conducted in 1992 for the *Expansion of the Wastewater Treatment Plant at Fort Kamehameha Environmental Assessment*.[21] These surveys, performed in the vicinity of the site proposed for the underground injection alternative, did not identify any species listed as threatened or endangered. Since the terrain, soil conditions, and vegetation appear to be similar at both locations, it is highly unlikely that any listed species would be found in the areas proposed for the underground injection alternative.

For consistency with Executive Order 13186, *Responsibilities of Federal Agencies to Protect Migratory Birds*, federal agencies taking actions that have, or are likely to have, a measurable negative effect on migratory bird populations must develop and implement a Memorandum of Understanding with the USFWS that promotes the conservation of migratory bird populations. Because it is not known if the areas proposed for construction of the underground injection alternative serve as migratory bird habitat, an additional survey would be required to determine if migratory bird habitat would be impacted by this alternative.

Much of the area proposed for the injection well field (see Figure 2.3-1) is a jurisdictional wetland (see Figure 3.5-1). A portion of this wetland area (estimated to be approximately 20 percent) would be regraded and would no longer be wetland due to construction of this alternative. For consistency with Executive Order 11990, *Protection of Wetlands*, special effort during design and construction will be needed to address potentially adverse impacts on the wetlands. The impacts will be associated with grubbing and grading activities for construction of access roads and injection wells. In addition to loss of wetland area, construction could alter the wetland hydrology, resulting in irreversible changes to the wetland biota. A Department of the Army permit will be required for work in the wetlands.

If the injection wells eventually deteriorate to the extent that additional injection wells are needed, possible injection well field site(s) would need to be surveyed to determine the potential for protected species or habitats to be adversely impacted. The results of such surveys may be a determining factor in site selection for additional injection wells.

4.6.3.3 No Action

No significant impacts to protected species or designated critical habitats are anticipated as a result of construction of this alternative, since no construction activities are proposed.

[20]Air Force Center for Environmental Excellence (June 1997) *Final Integrated Natural Resources Management Plan for Hickam AFB, Oahu; Bellows AFS, Oahu; Hickam POL Pipeline, Oahu; Kaala AFS, Oahu; Kaena Point STS, Oahu; Kokee AFS, Kauai; and Palehua Solar Observatory, Oahu (15th Air Base Wind Installations).*

[21]Belt Collins & Associates (August 1992).

4.6.4 Operational Impacts and Mitigation

4.6.4.1 Replacement Outfall (Proposed Action)

Green sea turtles may shelter at the new diffuser site, which would result in an increased number of turtles at that location. This would not be an adverse impact, so no mitigation would be required. No significant impacts to other listed species or coral reef ecosystems are anticipated to result from operation of the proposed outfall.

As stated in Section 4.6.2.2, informal Section 7 consultations with the USFWS and NMFS were completed in 1997 and both agencies concurred that the construction and operation of the proposed outfall are not likely to affect listed species or designated critical habitat (see Appendix II-m). Since plans for the operations of the proposed outfall have not changed since the initial informal Section 7 consultations with USFWS and NMFS, the concurrence of these two agencies with the determination that the proposed action is not likely to affect listed species or designated critical habitat is still applicable to the operations of the proposed outfall.

4.6.4.2 Underground Injection

Operation of the conceptualized underground injection system would not impact protected terrestrial species. The information required to determine if this alternative would impact marine biota or other species living in the coastal environment, and the extent of such an impact is presently unavailable. This lack of information prevents a more meaningful assessment of risks to protected species. The extensive testing that would be required to evaluate potential impacts on the aquatic environment would be prohibitively expensive.

It is possible that the operation of the injection wells may affect protected species living in the coastal environment by discharging through the caprock aquifer into the ocean. Existing information regarding the specific geologic and hydrologic characteristics of the proposed injection area is insufficient to determine where and at what concentration the injected effluent would enter the ocean and whether impacts on marine biota would result. As indicated in Section 4.4, the hydraulic properties of the caprock aquifer on the east side of the Pearl Harbor Entrance Channel are extremely variable and poorly defined. Because the concentration and location at which the injected effluent would enter the ocean is unknown, the potentially significant impact of this alternative upon the habitat of protected species cannot be determined. This potentially significant impact would be an inherent risk of implementing this alternative.

4.6.4.3 No Action

Although the no-action alternative is not expected to impact terrestrial wildlife or wetland areas, there is the potential for operations to impact marine biota if wastewater flows increase in the future. Increased flows could potentially cause increased nutrient and/or pollutant loadings to the estuary, which may have detrimental effects on living coral and other protected marine biota in the vicinity of the existing outfall.

4.6.5 Cumulative Impacts

4.6.5.1 Replacement Outfall (Proposed Action)

No significant cumulative impacts to listed species or coral are anticipated as a result of the proposed action.

4.6.5.2 Underground Injection

There is a potential for injected effluent to enter nearshore waters and to have a cumulative impact with surface runoff on protected species living in the coastal environment. However, if the treated effluent from the injection wells were to enter Open Coastal Waters, the cumulative impact of the HWWTP and SIWWTP outfalls and the injected effluent would probably be limited by the large dilution available in Open Coastal Waters.

4.6.5.3 No Action

As stated in Section 4.6.4.3, future increased flows to the WWTP could potentially cause increased nutrient/pollutant loadings to the estuary. These increased loadings along with runoff from nonpoint sources could potentially have a significant cumulative impact on living coral and other protected marine biota in the estuary.

4.7 Cultural Resources

4.7.1 Background

Although most of the outfall construction will occur on submerged lands in the Pearl Harbor Entrance Channel, some relevant information was obtained from archaeological investigations, which were conducted as part of the 1992 EA for expansion of the WWTP at Fort Kamehameha. These references are listed below.

- Kanalei Shun and Allan Shilz, *Preliminary Report, Surface and Sub-Surface Archaeological Survey of Construction Areas at Wastewater Treatment Plant at Fort Kamehameha, Oahu Hawaii*, March 1991. This study investigated surface and subsurface archaeological remains within the family housing area of Fort Kamehameha.

- Conrad Erkelens and J. Stephen Athens, *Archaeological Review and Recommendations for the Fort Kamehameha Sewage Treatment Plant Expansion and Housing Relocation Plans*, March 1992. This study examined and documented the archaeological structures, cultural artifacts, burial remains, and historical background of the Fort Kamehameha project area.

- Ogden Environmental and Energy Services, *Phase I Archaeological Subsurface Testing and Data Recovery at Fort Kamehameha Wastewater Treatment Plant*, April 1996. This study examined cultural features, fishpond remnants, and historical land uses of the WWTP site.

- Ogden Environmental and Energy Services, *Phase II Archaeological Subsurface Testing and Data Recovery, Wastewater Treatment Plant at Fort Kamehameha, Pearl Harbor, Oahu, Hawai'i*, July 1997 (Prefinal Report). This report presents the findings of testing and data recovery at various locations in the housing area and a parcel east of Kamehameha Pier.

- Ogden Environmental and Energy Services, *Phase III Archaeological Monitoring and Emergency Data Recovery at Fort Kamehameha Wastewater Treatment Plant, Pearl Harbor, Oahu, Hawai'i*, July 1997 (Prefinal Report). This study is a continuation of archaeological investigations in support of construction activities for the expansion project. Archaeological monitoring, testing, data recovery, and removal of burials were carried out.

4.7.2 Significance Factors

The factors considered in determining a significant impact to cultural resources include:

- The extent or degree to which the implementation of an alternative would result in a substantial and adverse change in the characteristics that qualify the cultural resource for listing in the National Register, and

- The adequacy of measures to avoid, minimize, or mitigate the impacts.

4.7.3 Relevant Environmental Conditions

According to the 1992 Erkelens and Athens survey, traditional Hawaiian use of the Fort Kamehameha area is not well documented in the historical literature and archival sources. However, its location at the mouth of Pearl Harbor suggests it likely would have been of some importance. Fort Kamehameha is within the traditional land unit (*ahupua'a*) of Halawa. Legendary accounts pertaining to this area are documented in various sources, but they provide no additional factual data regarding the prehistoric settlement.

Archaeological investigations for the WWTP expansion project have recovered subsurface cultural remains indicating prehistoric and historic use and occupation of the Fort Kamehameha area. The earliest use, which has been radiocarbon dated to A.D. 1200-1550, appears to be temporary habitation as evidenced by midden pits and one burial feature. The late prehistoric to historic period use is indicated by human and animal burial features and by trash pits containing nineteenth-century artifacts. Evidence of U.S. military use during the early twentieth century includes roadbeds, remains of wooden and concrete structures, and trash pits containing ceramics, bottles, and metal.

A Bishop Museum report describes the Pearl Harbor Entrance Channel as the gateway of the Halawa *ahupua'a*.[21] A fish trap or weir may have been located at Bishop Point in the Pearl Harbor Entrance Channel, approximately 650 m (2,100 ft) northwest of the WWTP. The weir was used by early Hawaiians to catch deepwater fish entering the harbor. Weirs were unique in Hawaii. Single stone lanes (*pa*) guided fish into waiting nets and were oriented to catch fish according to either the inflow or outflow of the tides. The Halawa *pa* were eventually removed to build a small pier. No remnants of the *pa* have been found. Some of the other Pearl Harbor weirs were associated with *ko'a* (fish shrines); religion and fish production were often closely associated with fish weirs. However, no evidence exists that the *pa* located near Fort Kamehameha had a fish shrine.

The entire Pearl Harbor basin is a National Historic Landmark. Any artifact or relic that is related to the December 7, 1941, Japanese attack would qualify as having potential historic significance. The only relic near the project locale that would qualify under this criterion is a possible Japanese midget submarine, sunk in the Pearl Harbor channel. According to a report prepared by the

[21]P. Christian Klieger (1995) *Nā Maka o Hālawa, A History of Hālawa Ahupua'a, Oahu.*

National Park Service, an underwater sonar search indicated the presence of a Japanese Kohyoteki submarine in approximately 275 m (900 ft) of water, outside the harbor mouth.[22] (The submarine is located near the western section of the channel wall and approximately 4.2 km [2.6 mi] seaward from the project site.)

4.7.4 Construction Impacts

4.7.4.1 Replacement Outfall (Proposed Action)

It is unlikely that excavation of the underwater portion of the site would affect any cultural resources. To date, no Hawaiian archaeological artifacts or structures have been found there. It is not anticipated that any burial sites will be found seaward across the reef flat due to the characteristics of the seashore, which is a reef area with hard substrate. There has been no indication that the outfall system will disturb any World War II undersea relics (whether Japanese mini-submarines or downed aircraft). The proposed outfall alignment does not cross any possible archaeological sites; much of the route is in the previously dredged channel.

Although a small developed portion of land immediately fronting the WWTP will be excavated for connection of the new outfall to the existing discharge manifold, this area has already undergone a complete archaeological data recovery for the WWTP expansion project, so no impacts on cultural resources will result from this activity.

It is highly unlikely that the establishment of construction staging areas designated in Figure 2.2-5 would affect cultural resources. Although most of the proposed staging area is within an area designated as having a high probability of finding archaeological resources,[23] it is unlikely that archaeological resources will be affected at the specific areas designated for staging. The area north of the WWTP at Fort Kamehameha is paved and will remain so throughout the construction staging process. The unpaved areas to the south and east of the WWTP were used for staging and dewatering purposes in support of the WWTP expansion project. In addition, previous archaeological testing conducted in these areas did not reveal significant subsurface cultural deposits.[24]

4.7.4.2 Underground Injection

Construction of the injection well system would require excavation at the individual well sites, along the transmission pipeline corridors, and at the WWTP, as described in Chapter 2. Although these excavations would be located in developed areas, there is potential for cultural resources to be encountered given the shallow nature of most archaeological deposits previously found at Fort Kamehameha (within 30 cm [12 inches] of the surface).

Prior to and during investigations conducted in the early 1990s for expansion of the WWTP at Fort Kamehameha, buried human remains were inadvertently discovered. The remains of several adults and a child were found during the excavation for Secondary Clarifier No. 4 (see Figure 1.7-2) in 1991-1992. An intact prehistoric cultural deposit containing charcoal flecking and numerous features with a carbon dating range of A.D. 1493 to 1814 (83 percent probability) and A.D. 1391

[22]Daniel J. Lenihan (1989) *Submerged Cultural Resources Study, USS Arizona Memorial and Pearl Harbor National Historic Landmark.*

[23]Air Force Center for Environmental Excellence (June 1997).

[24]Belt Collins & Associates (August 1992).

to 1638 (96 percent probability) was also found. Thus, there is also a high likelihood of encountering additional human burials and cultural deposits in the area.[25]

If the injection wells eventually deteriorate to the extent that additional wells are needed, possible injection well field site(s) would need to be surveyed to determine the potential for cultural resources and human burials to be adversely impacted by well field construction activities. The results of such surveys may be a determining factor in site selection for additional injection wells.

4.7.4.3 No Action

No significant impacts to archaeological or historic resources are anticipated as a result of the no-action alternative because no construction activities are proposed.

4.7.5 Operational Impacts

None are anticipated from the proposed action, underground injection, or no action.

4.7.6 Cumulative Impacts

None are anticipated from the proposed action, underground injection, or no action.

4.7.7 Mitigation

The Navy consulted with the State Historic Preservation Officer (SHPO) in the Department of Land and Natural Resources (DLNR) as it developed means to avoid, reduce, or mitigate any potentially detrimental effects. In a letter dated January 6, 1998, the SHPO concurred with the Navy's determination that the proposed action will have "no effect" on significant historic sites.[26]

If archaeological objects or human remains are encountered during construction of the outfall, work will be stopped. The Navy archaeologist, SHPO, Office of Hawaiian Affairs, Hui Malama I Na Kupuna O Hawaii Nei, and Oahu Island Burial Council will be immediately notified. Human remains will be treated in compliance with NAGPRA.

For the underground injection alternative, some construction excavation would occur in areas where archaeological testing and recovery has not occurred and where archaeological resources may be present. If remains or artifacts are discovered during construction of the underground injection alternative, the mitigation measures mentioned above would be followed.

No impacts to cultural resources are anticipated as a result of the no-action alternative; therefore, no mitigation is required.

4.8 Public Health and Safety

This section addresses two distinct public health and safety issues associated with the proposed action and the underground injection and no-action alternatvies:

(1) The potential for ordnance items to be present along the construction corridor, and
(2) Potential presence of pathogens or toxins in recreational waters.

[25] Belt Collins & Associates (August 1992).
[26] See Appendix II-m.

Dangers from ordnance items are related only to outfall construction activities, while concern over the presence of pathogens or toxins in recreational waters is related only to the operations of the proposed action and the underground injection and no-action alternatives. Common safety concerns associated with all construction sites will be mitigated by routine access restrictions and are not addressed in detail.

For the underground injection alternative, no hazards from ordnance items are anticipated. Long-term impacts of operations may include elevated levels of nutrients and turbidity in the groundwater aquifer at the injection points. This impact would not be significant, because the injection wells would be located seaward of the DOH's underground injection control line and thus would not affect any aquifer used for supply of potable water.

It is not possible to determine conclusively if effluent injection wells would result in any public health impacts because information regarding the location at which the injected effluent would eventually reach the ocean is presently unavailable (see Section 4.4.5.2). The overall costs of obtaining such information, which would involve the installation of test wells and extensive testing and analysis, are prohibitive. Due to the uncertainties related to the injection of effluent on water quality, as it pertains to public health and safety, the reasonably foreseeable impacts of this alternative cannot be evaluated.

The no-action alternative has the potential to impact water quality in the estuary, if the influent flow to the WWTP were to increase. Based on existing evidence, this would not be expected to affect public health and safety from potential pathogen or toxin exposure.

This section concludes that the proposed replacement outfall discharge will not pose a long-term public health threat. As noted in Sections 4.8.2 and 4.8.4, the pathogen toxicity levels of the treated effluent will not present public health hazards or accumulate in the environment. No cumulative impacts upon public health are anticipated from the proposed outfall.

4.8.1 Significance Factors

4.8.1.1 Construction

For construction workers, the significance factor is the presence of construction activities in areas which may contain ordnance items.

4.8.1.2 Operations

Factors considered in determining a significant impact on public health and safety during operations include the extent or degree to which the implementation of an alternative would:

- Affect the number of recreational users exposed,
- Affect water quality of recreational waters,
- Affect whole effluent toxicity,
- Affect outfall plume visitation frequency, and
- Affect the accumulation of toxic chemicals in the environment.

Number of Recreational Users

For operations, the number of recreational users affected by the discharge is used as one of the factors to assess impact significance.

Water Quality Standards for Recreational Waters

HAR Chapter 11-54-08 specifies the following standard for recreational waters:

> *Within 300 meters (1,000 ft) of the shoreline, including natural public bathing or wading areas, enterococci content shall not exceed a geometric mean of seven per one hundred milliliters (100 ml) (0.211 pints) in not less than five samples collected over an equally spaced thirty day period.*

Enterococci indicate the presence of disease-causing pathogens from human fecal matter. The WWTP staff monitor the enterococci content of the secondary effluent. The discharge permit requires the monthly geometric mean to not exceed 133 colony forming unit (cfu) per 100 ml (0.211 pints). The impact will be analyzed by comparing the monitoring results to the above standard.

Whole Effluent Toxicity

Whole effluent toxicity reflects the aggregate toxic effect of an effluent measured directly by a toxicity test.[27] The WWTP at Fort Kamehameha uses two species for such tests: *Tilapia mossambica* (1- to 30-day-old fish) and *Penaeus vannamei* (0- to 14-day postlarval-stage shrimp). These tests are conducted for a period of 96 hours. The survival rate, as a percentage of the number of organisms tested in whole effluent (i.e., 100 percent effluent), is monitored. The rate of survival reflects the toxicity of the effluent: the higher the survival rate, the lower the toxicity. Under the existing permit the effluent limitation is set at 80 percent survival rate for the whole effluent.

Accumulation of Toxic Chemicals in the Environment

Toxic materials released to the environment in low concentrations may accumulate in soils or tissues of organisms, thereby presenting routes of exposure to elevated levels of these materials. The presence of these conditions at the existing outfall would indicate the degree of such exposure potential.

The concentrations of various toxic chemicals, such as metals, total cyanide, chlorinated pesticides, and polychlorinated biphenyls (PCBs), in sediment and fish samples were compared to background levels in Pearl Harbor sediments and in fish collected from control locations to further assess the potential impact of toxic constituents.

Effluent Chemistry

HAR Chapter 11-54-04 specifies that continuous discharges through submerged outfalls shall not contain:

[27] 40 CFR, Part 122.2.

"...pollutants in 24-hour average concentrations greater than the values obtained by multiplying the minimum dilution by the standards in paragraph (3), above, for the prevention of chronic toxicity."

For chemicals listed in HAR 11-54-04 that have no established standard, the limits listed in the National Oceanic and Atmospheric Administration (NOAA) Screening Guidelines can be used to provide some idea of chronic toxicity.

Using a minimum dilution factor of 1,200:1, which is the dilution factor at the estimated ZOM boundary, effluent regulatory limits can be calculated. Laboratory results for 24-hour samples can then be compared to the calculated regulatory limits to determine if the effluent will significantly impact the receiving environment.

Plume Visitation Frequency

Long-term health impacts of the plume for the proposed action were also examined by using the outfall plume visitation frequency, which is the possibility of the outfall plume surfacing at a particular location. As discussed in Appendix XI, the outfall plume transport pattern varies with the season: westward transport is more pronounced in summer; eastward transport with increased diffusion and variation predominates in winter. Plume surfacing is more frequent during winter than during summer (see Table 2.2-1).

4.8.2 Relevant Environmental Conditions

4.8.2.1 Construction

Ordnance items have been observed in and removed from the vicinity of the proposed outfall alignment. Based on observations from various dives, there are no known ordnance items within the established construction corridor.

4.8.2.2 Operations

Number of Recreational Users

Ocean activities in the outfall vicinity include reef walking, fishing, scuba diving, shell collecting, swimming, snorkeling, boating, and thrill craft riding. Offshore ocean activities are concentrated on the reef flat or slope. Because the area is within the Naval Defensive Sea Area, its users are mainly military personnel. Although the reef flat is one of the most heavily used among the recreational sites surveyed, it is not used as often as other offshore reefs in the region (e.g., Ewa Beach). This is probably because other reefs provide more recreational opportunities and do not have access restrictions.

Water Quality Standards for Recreational Waters

The enterococci content in the treated effluent meets the existing permit effluent limitations (Table 4.8-1). The two-year (1995-1996) average of monthly geometric mean (or geomean) meets the effluent limitation, which is established as follows:[28]

[28]State of Hawaii, Department of Health (April 2000).

Permit Effluent Limitation = Recreational Water Quality Standards x Initial Dilution Factor[29]
= 7 cfu/100 ml (cfu/0.211 pints) x 19
= 133 cfu/100 ml (cfu/0.211 pints)

Table 4.8-1
Effluent Enterococci Content in CFU/100 ml (CFU/0.211 pints) for 1995 and 1996[30]

Two-Year	Monthly Effluent Geomean	Permit Effluent Limitation*
Average	8.99	133
Maximum	29.6	133
Minimum	1.74	133

*The enterococci limitation is for the monthly geometric mean of weekly sampling and analysis.

Whole Effluent Toxicity

The whole effluent toxicity is also within the permit limitations without dilution. The two-year data (1995-1996) are summarized in Table 4.8-2.

Table 4.8-2
Toxicity in Percentage of Survival for 1995 and 1996

Two-Year	*Tilapia mossambica*	*Penaeus vannamei*	Permit Effluent Limitation[31] *
Average	99	95	80
Maximum	100	100	-
Minimum	85	89	-

*The toxicity limitation is for each individual sample analysis.

Accumulation of Toxic Chemicals

An evaluation of certain potentially toxic chemicals in sediments surrounding the existing outfall was conducted using samples obtained during the early planning phases of the replacement outfall.[32] Sediment samples were obtained from two locations, one location immediately adjacent to the existing outfall and one location about 610 m (2,000 ft) toward the ocean in the channel bottom. Samples from these two locations were compared with each other and against background averages for Pearl Harbor, obtained from literature of prior studies. Selected analytes included arsenic and heavy metals. For all analytes, the measured parameters at the adjacent and distant sampling locations were essentially the same, with no reflection of logarithmic decline in deposition as would be expected to occur if the outfall were the source of these contaminants. When compared with average values for the same constituents throughout the Pearl Harbor Entrance Channel, taken over a period of years, most constituents near the outfall were essentially the same or lower than the historic averages, with only copper being slightly higher. In summary, the physical sampling yielded no evidence that toxic constituents in the effluent are being deposited in the ocean environment.

[29]Initial dilution factor is determined by plume modeling studies.
[30]State of Hawaii, Department of Health (April 2000); and (September 14, 1990).
[31]State of Hawaii, Department of Health (September 14, 1990).
[32]SSFM Engineers Inc. (October 1996).

Fish samples were collected from the receiving waters fronting the WWTP and from offshore of Ala Moana Park at similar depths. The same three species of fish were collected at each sampling location. The Ala Moana fish samples were considered the control samples because no wastewater effluent is discharged into this area. The fish samples collected were analyzed for metals, chlorinated pesticides, and PCBs. The laboratory results are included in Appendix XIII. When sample results for fish from Pearl Harbor were compared to the sample results for fish collected from offshore of Ala Moana Park, results for pesticides, PCBs, total cyanide, and some metals were nondetectable. Those metals which were detected in the Pearl Harbor samples were present in concentrations of the same order of magnitude as the control samples from offshore of Ala Moana Park, with the exception of arsenic, as shown in Table 4.8-3. Although the arsenic result obtained for the Pearl Harbor fish sample, Jar 2, appears much higher than the results obtained for control samples, arsenic at this concentration is not considered a threat to public health and safety. Arsenic is a naturally-occurring trace element, and concentrations can vary in the environment by more than the amounts shown in Table 4.8-3.[33] Arsenic in plants and animals often combines with carbon and hydrogen to form organic arsenic compounds, which can build up in their tissues. These organic arsenic compounds are usually less harmful than the inorganic forms, and if ingested or absorbed, are normally excreted and do not bioaccumulate in humans.[34]

Table 4.8-3
Analytical Results (in mg/Kg) for Metals Detected in September 1998 Fish Samples

Analyte	Pearl Harbor Samples			Control (Ala Moana) Samples		
	Jar 1	Jar 2	Jar 3	Jar 4	Jar 5	Jar 6
Mercury	0.4	0.04	–	0.14	–	0.17
Antimony	–	–	2.97	1.91	2.35	0.618
Arsenic	–	4.56	–	–	1.34	1.69
Chromium	–	–	–	–	–	9.98
Copper	3.51	–	2.43	1.45	0.539	0.745
Nickel	–	–	0.423	–	–	0.491
Selenium	–	0.563	–	–	0.51	–
Zinc	3.95	7.63	3.5	4.34	8.66	3.84

Note: – = non-detectable
mg/Kg = milligram per kilogram
Three different species of fish were collected. Jars 1 and 4 contained the same fish species, as did Jars 2 and 5, and Jars 3 and 6.

Effluent Chemistry

Pursuant to a comment on the draft EIS submitted by the U.S. Environmental Protection Agency (USEPA), two 24-hour effluent samples were analyzed for various metals, volatile organics, pesticides, and herbicides using the appropriate USEPA methods in September 1998. The laboratory reports are included in Appendix XIII. All results were either nondetectable or present in concentrations much less than the applicable regulatory limits.

[33]David J.H. Phillips (1990) *Arsenic in aquatic organisms: a review, emphasizing chemical speciation.* Aquatic Toxicology, 16, pp. 151-186.

[34]Phillips (1990) and Agency for Toxic Substances and Disease Registry (April 1993) *ToxFAQs: Arsenic* at *http://astdr1.astdr.cdc.gov:8080/tfacts2.html* (internet web page).

Two 24-hour effluent samples were deemed sufficient because the effluent chemistry analysis was conducted only to determine the presence of constituents of concern to the USEPA and to confirm the findings of previous analyses (effluent monitoring [see Section 4.4.3], whole effluent toxicity, sediment sample analysis, and fish sample analysis). Based on the results of all the analyses conducted over time, the effluent from the WWTP at Fort Kamehameha is not considered a hazard to aquatic life or to public health and safety.

Plume Visitation Frequency

Plume modeling for this project was performed only for the diffusers considered for the replacement outfall, not for the existing outfall's diffuser. Thus, no estimate is made of plume visitation frequencies at the identified recreational sites for the existing outfall. However, most of Ahua Reef and the Channel "Wall," identified as sites 1 and 4 respectively on Figure 4.5-1, are within the ZOM of the existing outfall (see Figure 4.4-1).

4.8.3 Construction Impacts and Mitigation

4.8.3.1 Replacement Outfall (Proposed Action)

As indicated in Section 4.5.7, access to construction areas will be restricted for reasons of safety. All workers will be informed of the ordnance hazards before construction activities begin. Several ordnance items were observed in the proposed construction corridor during reef surveys. A survey to locate potential ordnance items along the outfall alignment was conducted in March and April 1999. During this survey, one projectile was observed in the channel hard reef area where water depths range from 7.9 to 17.1 m (26 to 56 ft), and five projectiles were observed in the vicinity of the diffuser end of the outfall. Navy EOD personnel removed and disposed of all known ordnance items within the proposed construction corridor, including the six projectiles discovered during the survey. There is potential, although highly unlikely, for additional ordnance items to be encountered during the construction of the outfall. Therefore, the construction contractor will be required to perform an independent visual survey for ordnance prior to commencement of work within the construction corridor using a diving unexploded ordnance specialist. In addition, the contractor will be required to scan the pile driving location prior to start of pile driving. The spacing between pile caps may be adjusted to avoid any anomaly that may be detected. If one or more ordnance items are detected during construction, work will be stopped in the affected area until the status of the ordnance can be investigated by EOD personnel, who are specially trained to work with ordnance. If it is safe to move the ordnance, EOD personnel will remove it from the project site and dispose of it. However, if the ordnance cannot be safely removed, the alignment of the outfall will be adjusted to prevent disturbance and possible accidental detonation of the ordnance. If it becomes apparent during project execution that in-place detonation of ordnance cannot be avoided, the Navy will reinitiate formal Section 7 consultation with NMFS prior to continuing construction. Based on these procedures, no significant impacts are expected.

4.8.3.2 Underground Injection

Since the excavation required for transmission pipelines and additional facilities at the WWTP would be located in developed areas, it is unlikely that hazards from ordnance items would exist in such areas. Thus, construction impacts on public health and safety from the underground injection alternative are not anticipated.

4.8.3.3 No Action

The no-action alternative does not involve construction. Therefore, construction impacts on public health and safety are not expected.

4.8.4 Operational Impacts and Mitigation

4.8.4.1 Replacement Outfall (Proposed Action)

The long-term discharge of the treated effluent will not be toxic to fish or other aquatic life or create health hazards for the area's recreational users. The existing permit effluent limitations, which are met most of the time, are based on the dilution factor of 19. With the initial dilution factor of the submerged plume ranging from 111:1 to 1,922:1 (see Table 2.2-1) for the proposed 46-m (150-ft)-deep outfall, the potential for the effluent to pose any significant health threat to the public, either through water contact immediately surrounding the outfall or through fish consumption, is extremely low.

Table 4.8-4 summarizes the visitation frequency for the two diffuser options at eight recreational sites during a 24-hour tidal cycle. As shown, the proposed 200-m (656-ft)-long diffuser at a water depth of 46 m (150 ft) has slightly lower visitation frequencies at these sites. The possibility of plume surfacing is the highest at the seaward end of the Pearl Harbor Entrance Channel near the site of the diffuser. However, the occurrence of such a plume is inconsequential due to the lack of toxicity and low enterococci concentrations in the effluent and the rapid dispersion and mixing near the diffuser. Therefore, no significant impacts on public health and safety will result from outfall operations.

Table 4.8-4
Visitation Frequency of Surfacing Plume (in percentage) at Representative Recreational Sites*

Recreational Sites**	Diffuser Length = 200 m (656 ft) Water Depth = 46 m (150 ft)		Diffuser Length = 400 m (1,310 ft) Water Depth = 21 m (70 ft)	
	Summer	Winter	Summer	Winter
Reef Flat	< or = 1	1-2	3-5	2-4
Hickam Harbor	< 1	1-3	3-5	4-8
Dropoff	about 1	1-2	4-6	4-5
Seconds	1-2	2-3	5-7	6-8
Firsts	1-2	2-3	5-7	7-10
Anchorage	1-2	3-5	6-8	11-15
Pearl Harbor Channel Entrance	4-10	10-20	12-32	20-40
Reef Runway Zone F	1-2	1-2	<1	2-4

* See Appendix XI.
** See Figure 4.5-1 for site locations.

4.8.4.2 Underground Injection

Underground injection of treated effluent has the potential to affect the water quality of the coastal environment and impact recreational sites. Although injected effluent would eventually reach the ocean, information regarding where it would enter the ocean and at what concentration is unavailable, and the cost of acquiring such information would be prohibitive (see Section 4.4.5.2). Should the injected effluent reach the ocean in the vicinity of a recreational site, the water quality may deteriorate, but direct impacts to the health and safety of the those that frequent the area cannot be estimated.

4.8.4.3 No Action

The no-action alternative may have a significant impact on public health and safety, should the volume of treated effluent discharged through the existing outfall increase. This alternative involves the continued use of the existing ZOM, which encompasses much of the estuary fronting the WWTP including Ahua Reef (see Figure 1.2-1). Users of Ahua Reef are the closest persons exposed to the discharge. With increased discharge, initial dilution and disinfection may not be sufficient to meet recreational standards on the reef.

4.8.5 Cumulative Impacts

4.8.5.1 Replacement Outfall (Proposed Action)

No significant cumulative health and safety impacts will result from construction or operation of the proposed outfall.

4.8.5.2 Underground Injection

There is potential for cumulative impacts to public health and safety if injected effluent enters nearshore waters already affected by pollutants from nonpoint surface runoff. As previously indicated, the information required to determine the location and concentration at which injected effluent would enter coastal waters is unavailable, and the cost of acquiring such information would be prohibitive. Thus, it is not possible to determine if the potential cumulative impacts would be significant.

4.8.5.3 No Action

If the WWTP at Fort Kamehameha were to receive a greater influent flow, there would be potential for cumulative impacts to public health and safety of users of nearshore waters from the increased nutrient/pollutant loading from the WWTP discharge and the surface runoff from nonpoint sources.

4.9 Navigation

Both the proposed action and no action have the potential to impact navigation. Navigational impacts may result from both construction and operational phases of the proposed action, while the no-action alternative would have only operational impacts. During construction, moored platforms in and around the Pearl Harbor Entrance Channel may interfere with navigation. During operations, the pile-supported section of the proposed outfall and the existing outfall pipe have

the potential to be damaged by emergency anchoring of a ship. The underground injection alternative is land-based and, therefore, would not impact navigation.

4.9.1 Methodology of Analysis

The construction methodologies and finished project conditions were considered for the proposed outfall. Where potential constraints to navigation were identified, those constraints were defined in terms of the factors and conditions below. These factors and conditions were then discussed with operational personnel at Naval Station Pearl Harbor, to determine the severity of navigational impairment imposed by the obstruction and to identify mitigating measures.

4.9.2 Significance Factors

Factors considered in determining a significant impact on navigation include the extent or degree to which the implementation of an alternative would:

- Obstruct the Pearl Harbor Entrance Channel.
- Increase the potential for anchor entanglement.

The potential for outfall damage from a ship's anchor was evaluated relative to emergency anchoring data in the approach to the Pearl Harbor Entrance Channel.

4.9.3 Relevant Environmental Conditions

The Pearl Harbor Entrance Channel is up to 400 m (1,300 ft) wide at its ocean end but tapers to about 300 m (990 ft) within the project area. The existing depth of the entrance channel is approximately 13.7 m (45 ft) in the inner channel, which is bounded by military land on both sides, and 15 m (50 ft) in the outer channel, which is located in Open Coastal Waters. The entrance channel is used by all vessels in the Pacific Fleet, including ships homeported at the Naval Base. According to discussions with Naval Station Port Operations, aircraft carriers enter and depart the harbor once or twice yearly. According to Port Operations records and recollections of Port Operations[35] personnel, there are no known occurrences of emergency anchoring in the approach to the Pearl Harbor Entrance Channel over a three-year period.

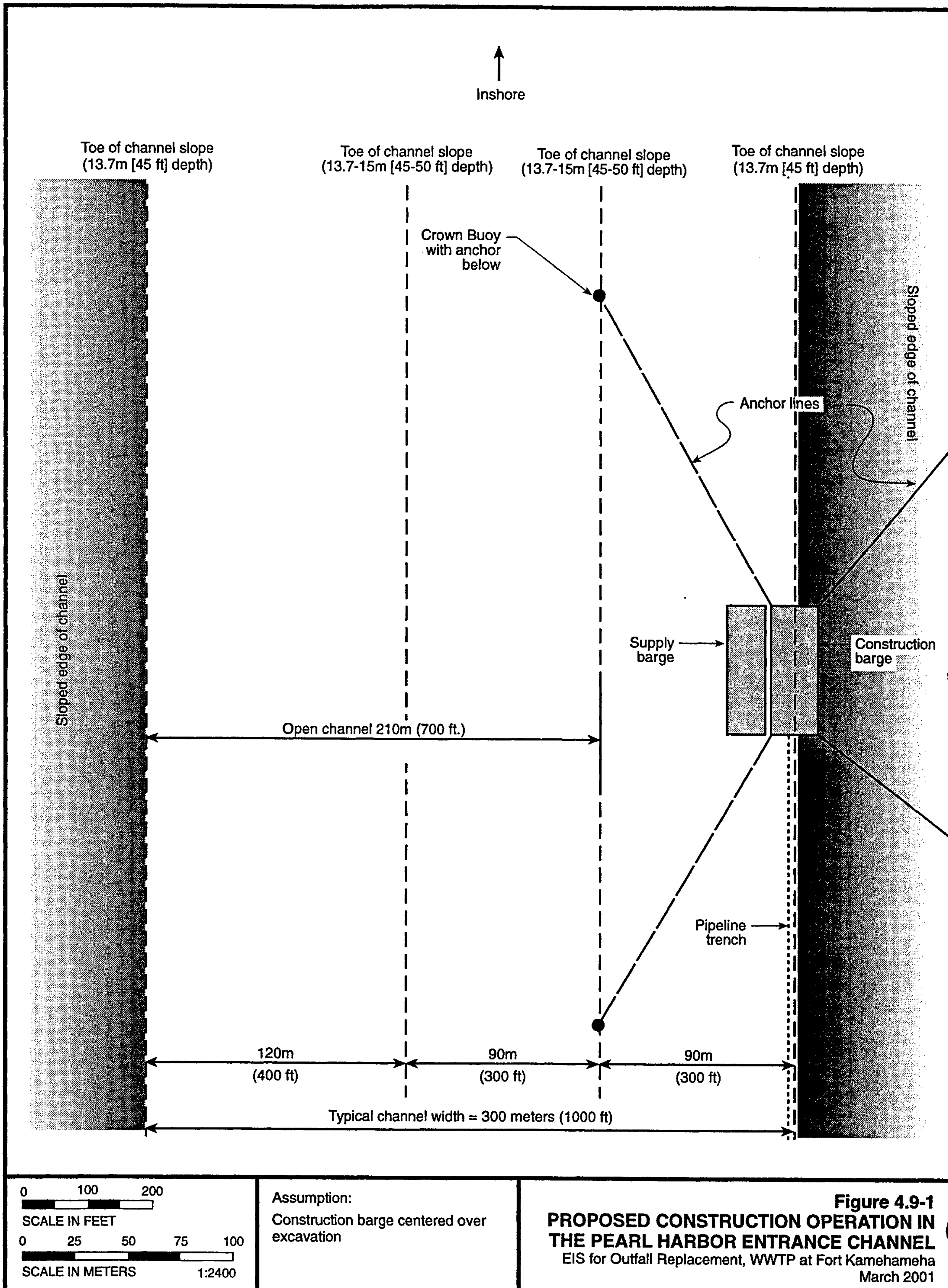
4.9.4 Construction Impacts

4.9.4.1 Replacement Outfall (Proposed Action)

Channel obstruction will occur when construction equipment is moored along the east side of the channel for trenching, pipe bedding, pipe laying, and trench backfilling. The duration of construction activities in the entrance channel is estimated to be eight months.

The obstruction may consist of two barges moored together. The barges may be secured by crown buoys, anchored out at 45° stem and stern. Although the two barges may extend approximately 40 m (130 ft) into the channel, the mooring buoys will extend out 90 m (300 ft) (Figure 4.9-1).

[35]Verbal communication with Director of Port Operations, Pearl Harbor (March 3, 1997).



Assumption:
Construction barge centered over excavation

Figure 4.9-1
PROPOSED CONSTRUCTION OPERATION IN THE PEARL HARBOR ENTRANCE CHANNEL
EIS for Outfall Replacement, WWTP at Fort Kamehameha
March 2001

Information provided by Port Operations[36] indicates that only aircraft carriers would encounter difficulty safely passing this obstruction. The scheduled passage of a single aircraft carrier could require that construction activities be stopped for as long as four days.[37]

The proposed 46-m (150-ft)-deep outfall diffuser is located approximately 500 m (1,600 ft) south of the 300-m (1,000-ft)-wide Hickam Harbor Entrance Channel and approximately 900 m (3,000 ft) offshore of the jetty at the west end of the reef runway (see Figure 2.2-1). These distances provide ample sea room for access to and from the channel during diffuser construction.

4.9.4.2 Underground Injection

Construction of underground injection wells would occur on land. Thus, no impacts on navigation are anticipated.

4.9.4.3 No Action

No construction activities are associated with the no-action alternative. Therefore, no navigational impacts are expected.

4.9.5 Operational Impacts

4.9.5.1 Replacement Outfall (Proposed Action)

Pile-supported outfall structures that protrude above the sea floor would be at risk of damage by an anchor dropped from a vessel under emergency conditions. Up to 500 m (1,600 ft) of pile-supported pipe may be vulnerable to such an impact. Although this risk is posed primarily by naval vessels, non-military recreational and commercial vessels are also authorized to operate in proximity of the channel. The anchors of small vessels may entangle the structure but are not likely to damage the outfall line or diffuser.

Although the anchors of larger vessels could damage the outfall structure, the structure is located where anchoring, even under emergency conditions, is unlikely. Based on this information, the degree of risk is deemed to be nonsignificant.

4.9.5.2 Underground Injection

Since the underground injection alternative is land-based, impacts on navigation from operations are not expected.

4.9.5.3 No Action

The existing outfall pipe is at risk of damage by an anchor dropped from a Navy vessel under emergency conditions, but the degree of risk associated with this incident is deemed not to be significant.

[36]Verbal communication with Director of Port Operations, Pearl Harbor (March 3, 1997).

[37]Should an aircraft carrier enter or depart the harbor, the construction barges must be demobilized and remobilized. Demobilization efforts will take approximately one day, as will mobilization efforts. Therefore, construction activities will cease for two days when a carrier enters or exits the harbor.

4.9.6 Cumulative Impacts

There will be no cumulative impacts upon navigation as a result of the proposed action, underground injection, or no action.

4.9.7 Mitigation

Potential channel obstruction by barges will be mitigated by warning mariners of the presence of equipment in the ship channel and, if required, relocation of the construction barges to allow the passage of aircraft carriers. Such relocations will be coordinated with Naval Station Port Operations. No blockage of the entrance channel will be allowed during any Rim of the Pacific exercises.

According to information provided by Port Operations,[38] aircraft carriers would be able to pass the anchor lines if they were placed at the toe of the channel slope, as shown on Figure 4.9-1. Placing the anchor lines at the toes of the channel would provide approximately 210 m (690 ft) of open channel and would not require movement of the construction barges for ship traffic.

Additional mitigation includes coordination with the Coast Guard to ensure the publication of a Notice to Mariners (NOTMAR) and proper placement of buoys and/or lights at the anchor locations in the entrance channel. All conditions of the Department of the Army permit as they apply to the new outfall pipe, barge, moored platform, and other floating equipment will be complied with.

Potential anchoring impacts of the proposed action and no action will be mitigated by ensuring the location of the underwater exposed piping is shown on NOAA nautical charts.

No navigational impacts are expected from the underground injection alternative. Thus, no mitigation is required.

4.10 Water as a Resource

On the island of Oahu, fresh water is a limited resource, the use of which must be carefully managed. Nearly all fresh water on Oahu comes from groundwater, a relatively inexpensive source to develop but one which has been exploited, it is contended, to its maximum sustainable potential. Meeting the island's future water demands will likely require a combination of conservation programs, irrigation with brackish groundwater, wastewater effluent reuse, storm water impoundment, and seawater desalination.[39]

Neither the proposed action nor the underground injection or no-action alternatives will have a significant impact on Oahu's water resources. None will adversely impact existing sources. However, reuse of effluent from the WWTP at Fort Kamehameha could help meet non-potable water demands. Its high salinity currently renders this use uneconomical. None of the alternatives, if implemented, would prevent future treatment and reuse of the effluent if economic conditions become favorable to do so.

[38] Verbal communication with Director of Port Operations, Pearl Harbor (March 3, 1997).

[39] Wilson Okamoto & Associates, Inc. (May 1994) *Oahu Water Management Plan, Initial Revision of Technical Reference Document*. Prepared for City and County of Honolulu, Department of General Planning.

4.10.1 Significance Factors

The proposed action and its alternatives have the potential to impact existing and future water sources. Groundwater is the major water source in the Pearl Harbor basin; approximately 595,000 m^3/day (157 mgd) was extracted from the Pearl Harbor Aquifer in 1990.[40] Other potential sources include stream diversion, which once supplied an average of 33,000 m^3/day (8.7 mgd), and brackish groundwater.[41] The proposed action or one of the alternatives proposed herein would have a significant impact if it substantially increases or decreases the sustainable yield of any groundwater aquifer used for water supply.

4.10.2 Relevant Environmental Conditions

In 1990, total water use on Oahu was estimated to be 1,420,000 m^3/day (375 mgd), of which 935,000 m^3/day (247 mgd) was for potable use. Although 1990 usage was 340,000 m^3/day (90 mgd) below the island wide sustainable groundwater yield of 1,760,000 m^3/day (465 mgd), the Pearl Harbor and Honolulu aquifers in the vicinity of Fort Kamehameha are almost fully exploited. Oahu's potable water demand is projected to grow by 215,000 m^3/day (57 mgd) between 1990 and the year 2010. To meet additional needs, the Board of Water Supply is proposing water conservation measures, development of additional groundwater sources, a 95,000 m^3/day (25 mgd) seawater desalination plant, and effluent reuse on the Ewa plain.[42]

4.10.3 Construction Impacts

No significant construction-related impacts on water resources are expected from the proposed action or the underground injection, or no-action alternatives. There are no construction activities associated with the no-action alternative. Construction of the proposed action, a marine outfall, will not affect existing sources of water. Although drilling mud may be introduced into local groundwater by well construction for the underground injection alternative and possibly for disposal of dewatering effluent associated with construction of the replacement outfall, the effects would be limited to the immediate vicinity of the wells and would be outside of potable aquifers.[43]

4.10.4 Operational Impacts

No significant operational impacts are expected from the proposed action or the underground injection, or no-action alternatives. The proposed action and the no-action alternative would discharge effluent to saline marine waters, away from groundwater or fresh surface waters. The underground injection alternative would discharge effluent into a non-potable aquifer. The aquifer would be out of the range of influence of potable supply wells and hence would not affect their yield or quality.[44] Due to its high salinity, effluent from the WWTP at Fort Kamehameha could not be injected to serve as an effective saltwater intrusion barrier.

[40] Wilson Okamoto & Associates, Inc. (May 1994).
[41] G.T. Hirashima (1971) *Availability of Streamflow for Recharge of the Basal Aquifer in the Pearl Harbor Area, Hawaii.* U.S. Geological Survey Water-Supply Paper 1999-B.
[42] Wilson Okamoto & Associates, Inc. (May 1994).
[43] State of Hawaii, Department of Health (no date) *Underground Injection Control Map, Pearl Harbor, Oahu Quadrangle.*
[44] State of Hawaii, Department of Health (no date).

4.10.5 Cumulative Impacts

Cumulative impacts will be the same as operational impacts. The proposed action, the no-action alternative, and the underground injection alternative will not have a significant cumulative impact on existing or future sources of water.

4.10.6 Mitigation

No significant adverse impacts are anticipated. Therefore, no mitigative measures are proposed.

4.11 Summary of Environmental Consequences

4.11.1 Comparison of Alternatives

Chapter 2 of this EIS discusses in detail the proposed action and alternatives. Preceding sections of this chapter discuss in detail the impacts that the proposed action and the underground injection and no-action alternatives would have on the environment and what steps could be undertaken to mitigate these impacts. This section summarizes and compares these impacts and recommends a preferred action. The preferred alternative, with proposed mitigation, has the least impact to the environment.

4.11.1.1 Comparison of Environmental Consequences

Based upon the analysis of environmental impacts presented in this chapter, a comparison was made between the proposed action, no action, and underground injection (see Section 2.9 and Table 2.9-2 for a matrix of the results of the comparison). The no-action alternative does not satisfy the purpose of the project, which is to reduce pollutant loadings from the wastewater discharge into the Pearl Harbor Estuary, or satisfy the need to meet all environmental and other regulatory constraints. This alternative, continued use of the existing outfall, would potentially result in future discharge permit violations (see Appendix I). The underground injection alternative may improve marine water quality; however, the information required to make this determination is unavailable and prohibitively costly to acquire. Also, the life-cycle cost of this alternative is substantially higher than that of the proposed outfall (Table 4.11-1). Combined with reliability questions and other risks and uncertainties associated with the fate of effluent injected underground, it is not the preferred alternative. Construction associated with the underground injection alternative would also potentially impact cultural resources in the area surrounding the WWTP, including human burials. It is possible that construction of the transmission line required for underground injection would encounter human burials, damage other cultural resources, and interfere with activities occurring in adjacent residential areas.

Table 4.11-1
Cost Summary for Alternatives

Alternative	Construction Cost	Annual O&M Cost	30-year Life-Cycle Cost
Replacement Outfall (Proposed Action)	$20,300,000	$95,400	$21,613,000
Underground Injection	$13,440,000	$1,560,000	$34,910,000
No Action	$0	$111,300	$1,533,000

The preferred alternative, replacing the existing outfall with an outfall in Mamala Bay, meets the purpose of and need for the project as identified above. Construction impacts associated with the proposed action are either short-term (related to specific construction activities) or can be mitigated using BMPs and/or SOPs.

Evaluation of the potential operational impacts of the preferred alternative shows the only significant impact to be on water quality within the ZOM. By definition, water quality standards are allowed to be violated within a designated ZOM. The size of the ZOM is smaller for the proposed action than no action. No ecological resources would be significantly impacted by diminished water quality within the proposed ZOM. Official ZOM boundaries will be determined by the DOH during processing of the NPDES permit for the new outfall. Based on effluent plume modeling, the estimated ZOM will be smaller for the proposed 46-m (150-ft)-deep diffuser than for the existing outfall or the 21-m (70-ft)-deep diffuser. Based on effluent plume modeling and a conservatively low estimate of the effluent quality from the WWTP, relocation of the outfall will not result in a violation of water quality standards outside of the estimated ZOM. The cumulative effect of the proposed outfall with other existing outfalls that discharge into Mamala Bay will not result in a violation of water quality standards. The relocation of the discharge from the Pearl Harbor Estuary may have a positive impact upon water quality in the estuary.

4.11.1.2 Comparison of Project Costs

Estimates of construction costs, annual operations and maintenance (O&M) costs, and 30-year life-cycle costs for the proposed action and each alternative are summarized in Table 4.11-1.

The proposed action, replacing the existing outfall with an outfall discharging to Class A Open Coastal Waters, is the second least costly alternative over a 30-year life cycle. The construction costs of a new outfall are relatively high, but O&M costs of an outfall, which consist primarily of receiving water quality monitoring, are relatively low compared to effluent reuse or the underground injection alternative.

The underground injection alternative is more costly than the replacement outfall or no action in terms of a 30-year life-cycle cost. Although construction costs for an injection well system are lower than for the proposed outfall, the annual O&M costs are much higher. This alternative also involves many undesirable risks and uncertainties, the costs of which cannot be reliably estimated. These risks and uncertainties are identified and discussed in Sections 2.3 and 4.11.1.4.

As indicated in Table 4.11-1, the no-action alternative is the least costly in terms of construction, O&M, and 30-year life-cycle costs. This alternative involves many limitations and risks that have not been assigned costs because of the many arbitrary assumptions that would be required. For example, an attempt to project the value of fines, legal costs, and administrative fees for potential permit noncompliance over a 30-year life cycle may not accurately represent the relative economic position of the no-action alternative in relation to the other alternatives considered. See Sections 2.4 and 4.11.1.4 for identification and discussion of these limitations and risks.

4.11.1.3 Comparison of Energy Requirements

Estimates of the average annual energy consumption for the proposed action, underground injection, and no action are presented in Table 4.11-2. Energy consumption associated with underground effluent injection consists primarily of energy requirements for effluent pumping.

Table 4.11-2
Energy Consumption Summary for Alternatives

Alternative	Average Annual Energy Consumption (kWh/year)
Replacement Outfall (Proposed Action)	<10,000
Underground Injection	560,000
No Action	<10,000

kWh/year = kilowatt hour per year

4.11.1.4 Risk and Uncertainty

Each of the alternatives involves some degree of risk and uncertainty associated with both the construction and operations phases.

Replacement Outfall (Proposed Action)

For this alternative, terrestrial subsurface conditions present a relatively minor risk because terrestrial excavation will be limited. The geotechnical explorations (see Appendix IV) have provided adequate information regarding subsurface conditions to limit construction risks to an acceptable level. Even after a prudent geotechnical analysis of subsurface conditions along the proposed alignment, there is some risk of encountering unforeseen conditions during construction. Management of this risk will be accomplished by coordinated efforts of the Navy, design engineers, geotechnical engineers, and construction contractors, which will minimize negative cost, scheduling, and quality impacts.

There is also a potential risk of encountering ordnance items within the construction corridor that cannot be picked up and carried away. In the unlikely event that one or more such ordnance items are detected within the established construction corridor, an engineering solution, consisting of realigning a portion of the outfall, will be implemented to avoid the ordnance. The realigned portion of the outfall will be located within the established construction corridor to provide the necessary clearance from the ordnance. This engineering solution will not create any additional impacts to the environment. In the event that an engineering solution cannot be implemented within the established construction corridor, the Navy will reinitiate formal Section 7 consultation with NMFS in order to destroy the ordnance by in-place detonation, prior to continuing construction.

The major operational risks are vulnerability of the outfall to:

- Damage from a ship's anchor,
- Damage from natural phenomenon such as seismic and storm activity, and
- Fouling of the diffuser from shifting sands on the marine bottom.

These risks will be managed in the design phase by using appropriate design criteria and analyses. Design criteria relevant to the first two risks include protection of the outfall and ease of repair should the outfall become damaged. For the third risk, the diffuser will be designed to minimize the potential for fouling.

Underground Injection

The major construction uncertainty associated with underground injection of effluent is terrestrial subsurface conditions along transmission line corridors. Uncertainties include conventional geotechnical considerations, the potential presence of human burial remains and other archaeological artifacts, and contaminated soils. The risk associated with these uncertainties is potential construction cost and scheduling impacts. Management of the risk by coordinated efforts of the Navy, design engineers, geotechnical engineers, project archaeologists, Native Hawaiian organizations, and construction contractors could minimize cost and scheduling impacts on the project.

The following are major operational uncertainties associated with effluent disposal by injection wells:

- Permeability of the subsurface strata.
- Number and depth of injection wells to provide the required capacity.
- Fate of the effluent after injection, which is dependent upon subsurface geology and the direction and velocity of groundwater flow at the point of injection.
- Locations at which the diluted effluent enters the coastal waters and whether it would result in long-term coastal water quality impacts.
- Rate of well capacity deterioration.
- Ability to effectively restore well capacity using available rehabilitation methods.

Risks associated with these uncertainties include the following:

- Potential need for a large number and/or very deep wells,
- Costly wastewater treatment upgrades (such as nutrient removal) if unacceptable coastal water quality impacts occur,
- Cost of unanticipated well maintenance procedures to maintain capacity, and
- Cost of future replacement wells when available rehabilitation methods are no longer able to restore well capacity.

Management of these risks would be primarily reactive, although appropriate planning and monitoring would assist in early problem detection. Such monitoring would allow development of solutions before coastal impacts or well deterioration became unacceptable.

No Action

Because this alternative involves no construction, the uncertainties and risks are all operational. The major uncertainties include:

- Long-term reliability and durability of the existing outfall,
- Future regulatory limitations to discharges through the existing outfall, and
- Quantity of future wastewater flows, which are dependent upon future land use in the service area.

The following risks are associated with these uncertainties:

- Potential for structural failure of the existing outfall.
- Future permit requirements for additional costly wastewater treatment upgrades or discharge relocation (see Chapter 2 and Appendix I).

- Increase in future wastewater flows, which could jeopardize permit compliance.
- Penalties and legal actions resulting from permit or regulatory noncompliance.

Management of these risks would present difficulties for the Navy Public Works Center, Pearl Harbor and Commander, Navy Region Hawaii, because it would primarily involve reacting to conditions beyond the control of these entities. Because of the long lead time for design, permitting, and construction of major WWTP upgrades and/or a replacement outfall, permit violations could persist for an extended period if future permit limitations were not attainable by the existing treatment and disposal system.

4.11.2 Preferred Alternative and Environmentally Preferred Alternative

Based on the information summarized above, the proposed action, that of constructing a new outfall in Class A Open Coastal waters, is the preferred alternative. The preferred alternative meets the purpose and need with the least risk and uncertainty. It consists of a 107-cm (42-inch)-diameter pipe from the WWTP effluent pump station to the 46-m (150-ft) depth, where it will terminate in a 200-m (656-ft)-long diffuser. The preferred alignment for construction of this new outfall is shown on Figure 2.2-1. Alignment of the diffuser section of the outfall will be parallel to the sea floor contours.

The preferred alignment optimizes environmental and economic factors by maximizing the use of the reef flat while avoiding environmentally sensitive areas. The bottom of the channel from the entrance point of the preferred alignment to the natural sea floor slope is relatively clear of silt or other material that would be potentially unsuitable or difficult to certify for ocean disposal after trenching. The alignment across the reef flat has been configured to avoid areas of high-density, well-established living coral. Subsequently, the chosen alignment will minimize the impact upon the areas with a higher density of living coral. Natural recruitment will replace the low-density, small coral colonies affected by construction, as periodically occurs after severe storm events.

Based on the reduced occurrence of a surfacing plume and the greater dilutions available when the plume does surface, the 46-m (150-ft) depth was selected over the 21-m (70-ft) depth for the diffuser location. The ZOM for the 46-m (150-ft)-deep diffuser, based upon nitrate + nitrite nitrogen as the limiting parameter, will be approximately 910 m (2,980 ft) long and 750 m (2,460 ft) wide. The 46-m (150-ft) depth is characterized by a sandy bottom and somewhat steeper slopes than the 21-m (70-ft) depth, but is a viable location for diffuser construction due to the relative stability of the sand. Slopes at the 46-m (150-ft) depth are slightly less steep than slopes immediately above and below that depth. The steeper adjacent slopes, characterized by loose, coarse sand, would not only require additional construction expense but would also threaten the long-term structural and functional stability of the diffuser.

The preferred alternative has associated environmental impacts, which can be mitigated. Table 4.11-3 summarizes the potential impacts during construction and operations and proposed mitigation measures for the preferred alternative.

Based on the analysis and comparison of environmental impacts of the proposed action and alternatives, the proposed action is also the environmentally preferred alternative. The preferred alternative minimizes the impacts upon the environment from construction and operations by applying mitigation measures. The resulting impact upon the environment is less than from the other alternatives evaluated in this chapter. Underground injection would require more land-based construction than the replacement outfall, would occur in an identified area of human burials, and has the potential to degrade nearshore coastal water quality. Because of the improved discharge

Table 4.11-3
Summary of Impacts and Mitigation for Proposed Action

ACTIVITY	IMPACTS	MITIGATION
Construction (all phases)		
Construction Staging	Short-term use of approximately 3 ha (7.5 ac) for staging and dewatering activities	Avoid sensitive areas and restore staging areas after construction.
Construction in the aquatic environment which may contain ordnance items	Explosion danger to construction workers	Survey construction corridor; dispose of ordnance items that are deemed safe to move; realign portion of outfall to avoid ordnance if it cannot be safely removed; if engineering solution cannot be implemented, reinitiate Section 7 consultation with NMFS.
Construction Phase I (WWTP Connection/Reef Flat Crossing to Entrance Channel)		
Mobilization and transport of equipment	**Traffic**	
	Short-term interference with traffic around WWTP and surrounding Hickam AFB	Post Notices of Construction related to delays; re-route traffic during delivery of materials; use traffic control personnel when needed.
	Noise	
	Noise of construction equipment	Limit construction operations to hours between 7:00 a.m. and 7:00 p.m.
Outfall construction on reef flat	**Aquatic Environment**	
	Increased turbidity during construction	Use BMPs to contain silt; design alignment to minimize damage to marine biota; establish spill response and containment plans.
	Damage to marine biota resulting from construction activities	
	Socioeconomic	
	Decreased commercial and recreational uses of the reef flat due to presence of construction equipment	Install barriers and signs and provide security to keep users out of the construction zone.
	Noise	
	Noise of construction equipment	Limit construction operations to hours between 7:00 a.m. and 7:00 p.m.

Table 4.11-3 *(continued)*

ACTIVITY	IMPACTS	MITIGATION
Construction Phase II (Entrance Channel to Diffuser)		
Mooring construction equipment in entrance channel	**Aquatic Environment**	
	Mooring system may damage living coral	Require construction contractor to propose a mooring system that will not damage living corals and to receive Navy approval of the plan with respect to coral protection prior to construction.
	Navigation	
	Barge anchors will obstruct Pearl Harbor Entrance Channel	Post NOTMAR and adhere to U.S. Coast Guard and Port Operations regulations on marking anchor locations.
	Barge anchors will block portion of Pearl Harbor Entrance Channel during passage of aircraft carriers	Move barge when these vessels are to use the channel.
Outfall construction along entrance channel and in rock zone	**Aquatic Environment**	
	Increased turbidity during construction	Use BMPs to contain silt; design alignment to minimize damage to marine biota.
	Damage to marine biota resulting from construction activities	
	Socioeconomic	
	Decreased commercial and recreational uses of the work area due to presence of construction equipment	Post signs along shoreline, clearly delineate construction zone, and implement security measures to keep users away from construction zone.
	Navigation	
	Potential to entangle a ship's anchor and damage outfall during emergency anchorings	Submit revision to NOAA marine charts to locate obstructions.
	Noise	
	Noise of construction equipment	Limit construction operations to hours between 7:00 a.m. and 7:00 p.m.

Table 4.11-3 *(continued)*

ACTIVITY	IMPACTS	MITIGATION
Construction Phase II (Entrance Channel to Diffuser) *(continued):*		
Construction of pile-supported outfall pipe and diffuser	**Aquatic Environment**	
	Minor localized increases in turbidity resulting from pile driving	No mitigation is required.
	Damage to marine biota resulting from construction activities (very limited area)	
	Socioeconomic	
	Decreased commercial and recreational uses of the areas at the end of the entrance channel due to presence of construction equipment	Post NOTMAR indicating presence of underwater obstructions and construction equipment and clearly delineate construction zone.
Operations Phase		
Disposal of treated wastewater into Class A Open Coastal Waters	**Aquatic Environment**	
	Potential for exceedence of water quality standards inside the ZOM	Allowed under DOH definition of ZOM in permit; no mitigation is required.
Presence of outfall pipe and diffuser above ocean bottom	**Socioeconomic**	
	Potential for alteration of type and frequency of impacts on commercial and recreational uses around the diffuser	Submit revision to NOAA marine charts to locate obstructions.

location and effluent dilution provided by the replacement outfall, the no-action alternative is not the environmentally preferred alternative.

4.12 Irreversible and Irretrievable Commitments of Resources

The selection of the preferred alternative has associated with it both irreversible and irretrievable commitments of resources. The construction of the outfall will require the use of physical resources, including construction materials and fuel for equipment, and human resources, including planning, management, and construction labor. Wastewater effluent that is disposed into marine waters is lost for terrestrial reuse. However, the estimated cost to desalinate the effluent to a level acceptable for non-potable water use does not make reuse an economically viable alternative at the present time. Construction of the outfall does not preclude the future use of effluent from the WWTP when technology, growth of non-potable demand, and economic factors make reuse a more viable alternative. The presence of the proposed outfall would be beneficial for an effluent reuse project, because the outfall could be used for disposal into open coastal waters of brine, containing nutrients and other regulated constituents as well as excess and "nonspecification" effluent.

4.13 Unavoidable Impacts

The preferred alternative has the unavoidable but nonsignificant impact of creating a ZOM in Mamala Bay. Evaluation of diffuser placement options in this EIS has resulted in identifying a proposed discharge location with a small ZOM and a plume of minimal surfacing frequency at a reasonable cost. The preferred alternative also eliminates the ZOM of the current WWTP outfall, located primarily in the Pearl Harbor Estuary. The current ZOM has a constantly surfacing plume. The relocation of the outfall while not eliminating the wastewater discharge, moves it to a location that will allow better dilution in the marine environment.

4.14 Unresolved Issues of All Alternatives

The final size of the ZOM and the determination of the "critical" parameter to be used by DOH in its issuance of an NPDES permit for the proposed outfall are at the discretion of the DOH. These two issues are therefore unresolved at this time. However, as indicated in Section 4.4.5.1, no significant adverse impacts are anticipated.

The evaluation of the underground injection alternative also has several unresolved issues, including an incomplete understanding of how the injected effluent would interact with the groundwater aquifer and with adjacent marine waters (see Sections 4.4 and 4.11.1.4). Also, performance of injection wells cannot be accurately predicted. Resolution of either of these issues would require the installation and prolonged and extensive testing of one or more test wells at the proposed injection well location, which is beyond the scope of this EIS.

4.15 Short-term Use of the Environment Versus Long-Term Productivity

The ocean has the capacity to assimilate treated wastewater effluent. Use of the ocean for disposal of effluent from the WWTP at Fort Kamehameha will have no long-term detrimental effects on the ocean environment or its productivity.

Wastewater that is reused reduces the demands on aquifers for non-potable water purposes. The sustainable yield of the Pearl Harbor aquifer system is estimated by the Hawaii Commission on Water Resource Management to be approximately 696,000 m^3/day (184 mgd). Current withdrawal permits total approximately 635,000 m^3/day (168 mgd). In the future, should demand exceed the sustainable yield, the use of treated effluent to offset demand against the aquifer may be a cost-justifiable, economic, and environmentally suitable option compared to other alternative sources.

4.16 Possible Conflicts with Federal, State, or Local Land-Use Plans, Policies, and Controls

Each alternative, except no action, was designed to comply with applicable land-use plans, policies, and controls. Therefore, the alternatives, except no action, are equivalent from a land-use compliance standpoint before evaluation of environmental impacts and costs. The only conflict that has been identified with federal, state, or local plans, policies, and controls for the proposed action or the alternatives analyzed in this chapter is that no action does not meet the State's long-term goal of removing the discharge from Pearl Harbor Estuary.

4.17 Compliance with Executive Orders

In general, each alternative except no action was configured to comply with applicable Executive Orders. Compliance with the applicable Executive Orders are summarized below.

4.17.1 Floodplain Management

Executive Order 11988, which provides direction for federal agencies regarding floodplain management, is not applicable to the proposed action or the no-action alternative. It is applicable to the underground injection alternative, because the construction and operational activities associated with this alternative would occur in a floodplain area. The underground injection alternative would be designed to minimize impacts on the floodplain. Impacts would also be mitigated through the use of BMPs and SOPs.

4.17.2 Protection of Wetlands

Executive Order 11990 directs federal agencies to avoid long- and short-term adverse impacts associated with the destruction or modification of wetlands. Construction activities for the proposed action would not damage wetland areas. Construction staging areas have been delineated to avoid designated wetlands. Construction activities associated with the underground injection alternative would have potential to damage wetland areas, depending on the well site location. Therefore, this alternative would have to be designed to minimize and mitigate any impact upon wetlands. The no-action alternative does not affect wetland areas.

4.17.3 Coral Reef Protection

Under Executive Order 13089, federal agencies are required to identify which of their actions may affect U.S. coral reef ecosystems, protect and enhance the conditions of coral reef ecosystems, and, to the extent permitted by law, ensure that the actions they authorize, fund, or carry out will not degrade the conditions of the coral reef ecosystem. The pipeline alignment for the proposed action was designed and selected to avoid areas of coral growth to a maximum extent practicable. The underground injection alternative may affect the coral reef ecosystem, if injected effluent

discharges to nearshore waters. The no-action alternative may adversely affect living coral in the area if nutrient loadings to the estuary are increased.

4.17.4 Environmental Justice for Minority and Low-Income Populations

Under Executive Order 12898, federal agencies are required to address the potential for disproportionately high and adverse environmental effects of their actions on minority and economically disadvantaged populations. Based on the study of recreational, commercial, and personal consumptive users in the area of the proposed outfall (see Appendix IX), there is no indication that the user population primarily consists of minorities or economically disadvantaged persons. Therefore, the impacts of the proposed action will not disproportionately affect either minority or low-income populations. Similarly, neither the impacts of the underground injection alternative nor the impacts of the no-action alternative would disproportionately affect minority or low-income populations.

4.17.5 Protection of Migratory Birds

Under Executive Order 13186, federal agencies taking actions that have, or are likely to have, a measurable negative effect on migratory bird populations area required to develop and implement a Memorandum of Understanding with the USFWS that promotes the conservation of migratory bird populations. Construction activities for the proposed action will not impact migratory birds or their habitat. The outfall alignment has been designed to avoid areas where migratory birds are known to visit. Construction activities associated with the underground injection alternative could potentially damage migratory bird habitat, depending on the site location. Therefore, this alternative would have to be designed to minimize and mitigate any impact upon the habitat of migratory birds.

4.18 Energy Requirements and Conservation Potential

Ocean disposal is the least energy consumptive of the feasible alternatives. It would require less than 10,000 kWh per year compared to underground injection that may require as much as 560,000 kWh per year.

4.19 Urban Quality, Historical and Cultural Resources, and the Built Environment

Impacts of the proposed action, underground injection alternative, and no-action alternative on cultural resources were evaluated in Section 4.7. The proposed action would have little or no impact on cultural resources. The underground injection alternative has the potential to encounter subsurface archaeological objects or human remains during construction. The no-action alternative would not impact cultural resources because it involves no construction activities.

CHAPTER FIVE

LIST OF PREPARERS

CHAPTER FIVE
LIST OF PREPARERS

The following people were involved in the preparation of this document:

Preparer	Education	Contribution
Gary Kasaoka; Environmental Planner; Pacific Division, Naval Facilities Engineering Command	B.A. in Zoology M.S. in Science and Technology	Planner-in-Charge
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Stan Uehara, P.E.; Pacific Division, Naval Facilities Engineering Command	M.S. in Civil Engineering	Project Manager/Planner
Annie Griffin; Supervisory Archaeologist; Pacific Division, Naval Facilities Engineering Command	M.A. in Anthropology	Supervisory Archaeologist
John Goody; Environmental Planner; Belt Collins	B.S. in Electrical Engineering; Master's degree in Planning and General Management	Environmental Department Manager/Consultant; contributed to the organization and content of all sections; wrote Sections 4.9, 4.11.1.4, 4.11.2, and 4.12-4.19
Walter Billingsley; Environmental Engineer; Belt Collins	B.S. in Geography with Environmental Studies and in Civil Engineering; M.S. in Environmental Engineering	Project Manager; contributed to the organization and content of all sections; wrote Sections 2.1-2.3, 2.7-2.10, 4.1, 4.3, 4.11.1.2, and 4.11.1.3
Eric Halter; Environmental Scientist; Belt Collins	M.S. in Geology	Drafted Chapter 1 (except Sections 1.3 and 1.7) and Sections 4.11.1, 4.11.1.1, and 6.1
Sarah Young; Environmental Planner; Belt Collins	B.S. in Environmental Biology and Zoology; Master's degree in Public Health	Drafted Sections 4.4, 4.6, and 4.8
Fred Heyler; Civil Engineer; Belt Collins	B.S. in Civil Engineering; M.S. in Civil Engineering, Water Resources	Drafted Sections 2.4, 2.5, 2.6, and 4.10
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Preparer	Education	Contribution
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Philip L. Bruner; Assistant Professor and Director, Museum of Natural History, BYU-Hawaii	M.S. in Zoology	Prepared bird survey report
John Clark; Ocean Recreation and Water Safety Consultant	B.A. in Hawaiian Studies and Master's degree in Public Administration	Prepared ocean activities survey report
Steven Dollar; Marine Research Consultants	Ph.D. in Chemical Oceanography	Prepared an assessment of water quality and marine community structure
Tom Nance; Tom Nance Water Resource Engineering	B.S. in Civil Engineering; M.S. in Civil Engineering	Prepared letter report regarding the feasibility of wastewater disposal wells
Robert Rocheleau; Ocean Engineer; Sea Engineering, Inc.	M.S. in Ocean Engineering	Prepared time-integrated plume modeling and dredging turbidity reports
Jim Barry; Ocean Engineer; Sea Engineering, Inc.	M.S. in Ocean Engineering	Prepared plume modeling report
Eiji Nakazaki; Senior Ocean Engineer; Sea Engineering, Inc.	Ph.D. in Ocean Engineering	Prepared plume modeling report
Mark Ericksen; Coastal Geologist; Sea Engineering, Inc.	M.S. in Geosciences	Prepared dredging turbidity report
James Kwong; Geotechnical Engineer; Woodward-Clyde	Ph.D. in Geotechnical Engineering	Prepared geotechnical studies and contributed to Section 2.4.4

CHAPTER SIX

AGENCIES, ORGANIZATIONS, AND PERSONS CONTACTED

CHAPTER SIX
AGENCIES, ORGANIZATIONS, AND PERSONS CONTACTED

6.1 Environmental Impact Statement Process and Public Involvement

The federal environmental impact statement (EIS) process allows for public comment so that the decision maker may be apprised of the range of opinions on issues of potential significance in regard to the proposed action. This section describes the EIS process and summarizes the public involvement to date.

6.1.1 Scoping

The EIS process began with a 30-day scoping period beginning September 11, 1996, when a Notice of Intent (NOI) to prepare this EIS was published in the *Federal Register* and two local newspapers. The scoping period included two public meetings to provide information to the public about the proposed action and to receive oral and written comments on the proposed action. The scoping period ended on October 18, 1996.

Issues raised at the public scoping meetings are documented in the comment letters included in Appendix II. A copy of the NOI, group memory, and sign-in sheets from these scoping meetings are also included in Appendix II. A full discussion of the issues raised during the scoping and evaluation period is found in Chapters 2 and 4.

6.1.2 Draft Environmental Impact Statement and Final Environmental Impact Statement Process

Following the scoping period, the draft EIS (DEIS) was prepared, incorporating public comments on issues of importance. The DEIS was published in September 1997 and distributed to the interested parties listed in Appendix II. Upon publication of the DEIS, a Notice of Availability and announcement of public hearing for the DEIS was published in the Federal Register, two local newspapers, and the Office of Environmental Quality Control Bulletin, which allowed for a 45-day period for public review and comment on the draft document. Copies of the written comments submitted are included in Appendix II. During this 45-day comment period, a public hearing was held to allow an opportunity for public comments on the findings of the DEIS. Only two members of the public attended the hearing. Both of them also submitted written comments, which are included along with the Navy's response letters in Appendix II. All concerns and comments were considered during preparation of this Final EIS (FEIS) and were addressed in the FEIS if relevant.

The FEIS is designed to inform the decision maker of the anticipated significant impacts of the project and measures needed to mitigate adverse impacts. The document is not intended by the Council on Environmental Quality to be encyclopedic, but rather to focus on relevant issues so that a final decision is made based on knowledge of its potential environmental impacts.

Following consideration of alternative actions and environmental impacts, a Record of Decision (ROD) will be published. The ROD informs the public of the final decision on the proposed action, why the decision maker chose this particular alternative, any adverse impacts of this alternative, and actions the decision maker will take to mitigate adverse impacts.

6.2 List of Agencies, Organizations, and Persons Contacted

The agencies, organizations, and individuals consulted for this project are listed below. The NOI and DEIS distribution lists can be found in Appendix II. Those who commented on the NOI in writing or requested status as a consulted party are identified with an asterisk (*); those who submitted written comment on the DEIS are marked by a plus sign (+). Copies of the correspondence with those who submitted written comments on either the NOI or DEIS are reproduced in Appendix II.

Federal Agencies

Department of the Army, U.S. Army Corps of Engineers
+ Department of the Army, U.S. Army Engineer District, Honolulu
National Weather Service, Western Pacific Regional Fishery Management Council
+ U.S. Air Force
U.S. Department of Agriculture, Natural Resources Conservation Service
+ U.S. Department of Commerce, National Marine Fisheries Service
U.S. Department of Commerce, NOAA Fisheries Pacific Area Office
+ U.S. Department of the Interior, Environmental Policy and Compliance
* U.S. Department of the Interior, Fish & Wildlife Service
+ U.S. Department of the Interior, Geological Survey, Water Resources Division
U.S. Department of Transportation, Coast Guard
+* U.S. Environmental Protection Agency

State Agencies

Department of Agriculture
+* Department of Health
+* Department of Land and Natural Resources
+ Department of Transportation
Environmental Center, University of Hawaii
Marine Option Program, University of Hawaii
Office of Environmental Quality Control
+ Office of Hawaiian Affairs
+ Office of Planning
Sea Grant College Program, University of Hawaii
Water Resource Research Center, University of Hawaii

City & County Agencies

+ Board of Water Supply
+ Department of Land Utilization**
+ Department of Public Works**
+ Department of Parks and Recreation
+ Department of Wastewater Management**
Office of the Mayor
+ Planning Department**

State Legislators

Senator Rey Graulty**
Senator David Y. Ige
Senator Randall Y. Iwase**
Senator Norman Mizuguchi**
Representative Romy M. Cachola**
Representative Lennard J. Pepper**
Representative Roy M. Takumi

Honolulu City Council

Councilman Mufi Hanneman**
\+ Councilman Steve Holmes
Councilwoman Donna Mercado-Kim**

Neighborhood Boards

Aiea Neighborhood Board
Aliamanu Neighborhood Board
Pearl City Neighborhood Board

Organizations

Blue Ocean Preservation Society
Conservation Council of Hawaii
Earthtrust
Greenpeace Foundation of Hawaii
Hawaii Chapter American Fisheries Society
Hawaii Office Natural Resources Defense Council
Hawaii's Thousand Friends
Life of the Land
Mamala Bay Study Commission
Native Hawaiian Legal Corporation
Sierra Club Legal Defense Fund, Inc.**
Sierra Club Hawaii Chapter
The Ocean Recreation Council of Hawaii
Oahu Burial Committee
\+ Ahupua'a Action Alliance
Hui Malama Na Kupuna O Hawaii Nei
Pacific Basin Development Council
Save Our Bays and Beaches
Surfrider Foundation
Hui Malama Aina O Koolau
Women of Hale O' Papa

Private Individuals and Businesses

\+ Best Industries USA, Inc.
Robert Grace
Toni Yardley

** Organization names and elected officials listed were effective at the time the organizations/officials were consulted or contacted. City and County departments were reorganized into newly-created departments in July 1998.

CHAPTER SEVEN

REFERENCES

CHAPTER SEVEN
REFERENCES

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APPENDICES*

*Some appendices may contain non-metric units. Please refer to the Table of Contents for table of conversion factors.

APPENDICES

Appendix I

Letter from EPA to Navy Public Works Center and COMNAVBASE Pearl Harbor

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

JAN 2 4 1997

In Reply Refer To: WTR-7

CAPT James Delker
Commanding Officer
Navy Public Works Center-Pearl Harbor
Pearl Harbor, Hawaii 96860-5470

CAPT John Shrewsbury
COMNAVBASE-Pearl Harbor
Box 110 (Code N4)
Pearl Harbor, Hawaii 96860

Gentlemen:

Subject: EXPECTED VIOLATIONS OF THE NPDES PERMIT FOR THE FORT KAMEHAMEHA WASTEWATER TREATMENT FACILITY.

EPA expects the Fort Kam WWTF discharge through the existing outfall to violate NPDES permit limits for nutrients and toxics as derived from the State water quality standards. The discharge currently does not violate NPDES permit limits for nutrients and toxics because the expired 1990 version of the permit only required their monitoring. However the next version of the NPDES permit expected to be reissued later this year will impose the water quality standards for nutrients and toxics as end-of-pipe limits for the first time.

The expected end-of-pipe nutrient limits will be based on no increase in nutrient loads into Pearl Harbor, a Class 2 inland estuary, because it is a "water quality limited segment" for nutrients. This means the end-of-pipe nutrient limits will be derived from a statistical representation of past effluent concentrations and the original design flow rate of the Fort Kam WWTF. As a result, nutrient loadings will violate the expected limits if nutrient concentrations do not drop as flows rise above the original design flow rate. Compliance could be assured in two principle ways. First, flows could be discharged through a new deep ocean outfall into Class A open coastal marine waters which are not "water quality limited" for nutrients. Second, concentrations could be lowered through additional treatment steps to remove nutrients.

The NPDES permit is also expected to impose end-of-pipe toxics limits which will not be met unless metals concentrations drop. The size of the decrease would depend on what standards are in the permit, but violations are expected in any scenario. The Navy argues that the existing outfall qualifies under a State policy to apply only chronic standards as adjusted for dilution to "marine discharges through submerged outfalls". EPA asserts that acute standards unadjusted for dilution also apply because the existing outfall discharges to an estuary channel and the policy was meant to encourage use of deep ocean outfalls to open coastal waters where dilution is sure and any acute effects are far off-shore. EPA further recognizes that some unadjusted acute standards may be unattainable and has proposed BPJ standards attained by other source control programs.

Past samples collected for metals since 1991 would have violated the chronic plus unadjusted acute standards in all samples (100%) and the chronic standards adjusted for dilution alone in 3 of 17 (~20%) usable samples. Future discharges through the existing outfall could be expected to violate at similar rates. The expected violation rate with chronic and EPA's proposed attainable BPJ standards would be ~45%. This means continued discharge through the existing outfall would require an improved source control program no matter what toxics standards end up in the permit. On the other hand, no violations would be expected of the toxic standards for a deep ocean outfall providing an initial dilution factor of at least 45.

I hope this assessment of the expected violations of the new NPDES permit is helpful. If you have any questions, please call me at (415) 744-1900.

Sincerely yours,

Greg V. Arthur

Greg V. Arthur, Envr Engineer
CWA Compliance Office

cc: Alec Wong
Dept of Health, Clean Water Branch
P.O. Box 3378
Honolulu, Hawaii 96801

Ranold Fujioka
Navy Public Works Center-Pearl Harbor
Industrial Wastewater Pretreatment Branch (Code 641)
Pearl Harbor, HI 96860-5470

Joanne Higuchi
Navy Public Works Center-Pearl Harbor
Environmental Compliance Branch (Code 09E)
Pearl Harbor, HI 96860-5470

Aaron Poentis
Pacific Division
Naval Facilities Engineering Command
Pearl Harbor, Hawaii 96860-7300

Appendix II

Appendix II-a

Notice of Intent (Federal Register)

Citation	Rank(R)	Database	Mode
61 FR 47898-02	R 1 OF 1	FR	Page

96 WL 510927 (F.R.)
(Cite as: 61 FR 47898)

NOTICES

DEPARTMENT OF DEFENSE

Department of the Navy

Notice of Intent to Prepare an Environmental Impact Statement for the Proposed Construction of a Replacement Outfall for the Wastewater Treatment Plant at Fort Kamehameha, Pearl Harbor, Oahu, Hawaii

Wednesday, September 11, 1996

*47898 SUMMARY: Pursuant to Section 102(2)(c) of the National Environmental Policy Act (NEPA) of 1969, as implemented by the Council on Environmental Quality regulations (40 CFR Parts 1500-1508), the Navy announces its intent to prepare an Environmental Impact Statement (EIS) for the proposed construction of a replacement outfall for the existing wastewater treatment plant (WWTP) at Fort Kamehameha, Pearl Harbor, Oahu, Hawaii.

The action covered by the EIS is replacement of the existing outfall, which discharges into the entrance channel of a Class 2 inland estuary, with a multiport deep ocean outfall which will discharge into Class A open coastal marine waters. The proposed outfall will reduce nutrient mass loading on the Pearl Harbor estuary. The proposed action is consistent with the State of Hawaii's management plan for the Pearl Harbor estuary, pursuant to Section 304(1) of the Clean Water Act. The EIS will analyze reasonable alternatives for disposal of secondary treated effluent and will assess their direct and cumulative environmental impacts.

Navy will initiate a scoping process to identify significant issues for study in the EIS and to identify and notify parties interested in and affected by the proposed action. It is important that interested agencies, individuals, and organizations take this opportunity to identify environmental concerns and feasible alternatives that should be addressed in the EIS. Public scoping meetings will be held on 1 and 2 October 1996, during which oral comments may be presented. To allow all views to be shared, each speaker will be asked to limit comments to five minutes.

Interested parties are also invited and encouraged to provide written comments in addition to, or in lieu of, oral comments at the public meetings. Scoping comments should clearly describe specific issues or topics that the EIS should address. The scoping period for receipt of comments will end on 18 October 1996.

DATES/LOCATIONS: Two public scoping meetings will be held on Oahu: (1) Honolulu, Oahu: October 1, 1996, 7:00 - 10:00 pm, Washington Intermediate School, 1633 South King Street, and (2) Pearl Harbor, Oahu: October 2, 1996,

ENCLOSURE (/)

7:00 - 10:00 pm, Makalapa Elementary School, 4435 Salt Lake Boulevard.

FOR FURTHER INFORMATION CONTACT: Written statements and/or questions regarding the scoping process should be mailed no later than October 18, 1996 to Mr. Melvin Kaku (Code 23), Pacific Division, Naval Facilities Engineering, Pearl Harbor, HI 96860, telephone (808) 471-9338; fax (808) 474-4890.

SUPPLEMENTARY INFORMATION: The proposed action consists of constructing a 12,000-foot long, 42-inch diameter wastewater outfall extension, which will discharge through a multiport diffuser at a water depth of between 70 and 150 feet.

Construction activities include excavating an underwater trench across the shallow offshore limestone reef and in the Pearl Harbor entrance channel, installing pipe in the trench, and covering pipe with protective material. Construction equipment and supplies will be staged in the immediate vicinity of the treatment plant. Construction on the reef will require installation of a temporary earthen berm for equipment access; the berm will be removed after pipe installation. Construction in the channel will be carried out from one or more barges. Approximately 30,000 cubic yards of excavated material will be disposed at an approved offshore dredged material discharge site. Outfall piping will be assembled on land and floated to the outfall alignment. Piping in the trench will be supported by gravel beds and capped with concrete mats or tremie concrete. In shallow water, the top of the protective concrete mats will be approximately even with or just below the existing bottom contour. In deep water, the protective layer will be one meter below the design maintenance dredge depth. Construction activities will occur over a period of approximately 18 months. The existing outfall will be retained for emergency operations.

Alternatives to be evaluated include (1) no action, (2) several outfall alignments with variations of construction methodology, dredged material disposal, and diffuser depth and length, and (3) upland disposal of wastewater effluent, either by reuse or disposal through underground injection wells. The alternative outfall alignments all exit the existing WWTP discharge pump station and terminate at a depth of between 70 and 150 feet; they differ in the locations at which they cross the shoreline reef flat and enter deeper water. Construction method options include use of barges, use of a temporary berm across the reef flat, and possibly directional drilling. Dredged materials may be used to construct a temporary berm, disposed at the existing approved offshore disposal site, or disposed at an undetermined upland location. The upland disposal/reuse alternative for wastewater consists of constructing infrastructure to further treat WWTP effluent and redirect it to an undetermined upland site. The upland/underground injection alternative consists of constructing underground injection wells at suitable locations for effluent disposal.

Environmental issues to be addressed will include, but not be limited to, effects on surface and ground water quality, terrestrial and aquatic habitats, threatened or endangered species, cultural resources, infrastructure, traffic, noise and the socioeconomic environment. Direct, indirect, and cumulative impacts will be analyzed, and mitigation measures will be developed as required. Related regulatory processes will include a National Pollutant

Discharge Elimination System (NPDES) permit under the Clean Water Act (CWA), a Department of the Army permit under Section 404 of the CWA, and a Section 401 Water Quality Certification by the State of Hawaii Department of Health.

*47899 Dated: September 6, 1996.

D.E. Koenig,

LCDR, JAGC, USN, Federal Register Liaison Officer.

[FR Doc. 96-23198 Filed 9-10-96; 8:45 am]

BILLING CODE 3810-FF-P

61 FR 47898-02, 1996 WL 510927 (F.R.)

END OF DOCUMENT

Appendix II-b

Notice of Intent Distribution List

Organization/ Dept.	Addressee (last name)	Addressee (first name)	Title	Division	Address	Phone number	Comments received?	Receive DEIS/FEIS?
Accounting & Gen. Services	Tamura	Ms. Joslyn G.	Archivist		Dept. of Accounting & Gen. Services Iolani Palace Grounds Honolulu, HI 96813	586-0329		
Agriculture	Nakatani	Mr. James J.	Director		Department of Agriculture State of Hawaii 1428 South King Street Honolulu, HI 96814	948-0145		
Army	Army Directorate of Public Works				U.S. Army Garrison Hawaii ATTN: Environmental Management Office Schofield Barracks, HI 96857-5000			
Army	Cababa	Col. Robin R.	Acting Commander, Division Engineer		U.S. Army Corps of Engineers Pacific Ocean Division Building 230 Fort Shafter, HI 96858			
Army	Commander				U.S. Army Pacific ATTN: APEN Fort Shafter, HI 96858-5100			
Army	Dadey	Kathy			U.S. Army Corps of Engineers Pacific Ocean Division Building 230 Fort Shafter, HI 96858	438-9258 #15		
Army	Director of Engineering				Department of the Army U.S. Army Engineer District Honolulu Fort Shafter, HI 96858-5440			
Board of Water Supply	Sato	Mr. Raymond			Board of Water Supply City & County of Honolulu 630 South Beretania Street Honolulu, HI 96813	527-6180		
City Council	Hanneman	Councilman Mufi			City Council 530 South King Street, Rm 202 Honolulu, HI 96813	547-7008		

Organization/ Dept.	Addressee (last name)	Addressee (first name)	Title	Division	Address	Phone number	Comments received?	Receive DEIS/FEIS?
City Council	Mercado-Kim	Councilwoman Donna			City Council 530 South King Street, Rm 202 Honolulu, HI 96813	547-7007		
Coast Guard	Gehring	Rear Adm Howard B.	Commander		U.S. Coast Guard 300 Ala Moana Boulevard Honolulu, HI 96850	541-2051		
Commerce	Laurs	Dr. Michael	Director	National Marine Fisheries Service	2570 Dole Street Honolulu, HI 96822	943-1211		
Commerce	Naughton	Mr. John		NOAA Fisheries Pacific Area Office	2570 Dole Street Honolulu, HI 96822	973-2940 973-2941 (fax)		
Commerce	Simonds	Ms. Kitty	Executive Director	Western Pacific Regional Fishery Management Council	1164 Bishop Street, Suite 1405 Honolulu, HI 96813	522-8220		
Environmental Quality Control	Gill	Mr. Gary	Director		Office of Environmental Quality Control State of Hawaii 235 S. Beretania St.,Room 702 Honolulu, HI 96813	586-4185		
Hawaiian Affairs	Delaney	Ms. Linda		Land & Natural Resources	Office of Hawaiian Affairs 711 Kapiolani Boulevard, Suite 500 Honolulu, HI 96813	594-1934		
Health	Arizumi	Mr. Thomas	Chief	Environmental Management Division	Department of Health 919 Ala Moana Blvd., Room 300 Honolulu, HI 96814	586-4304		
Health	Lau	Mr. Denis	Chief	Clean Water Branch	Department of Health 919 Ala Moana Blvd., Room 309 Honolulu, HI 96814	586-4309		
Health	Miike, M.D., J.D.	Lawrence H.	Director		Department of Health State of Hawaii P.O. Box 3378 Honolulu, HI 96801	586-4410		

Organization/ Dept.	Addressee (last name)	Addressee (first name)	Title	Division	Address	Phone number	Comments received?	Receive DEIS/FEIS?
Health	Nagamine	Mr. Wilfred K.	Chief	Clean Air Branch	Department of Health 919 Ala Moana Blvd., Room 203 Honolulu, HI 96813	586-4200		
Health	Tulang	Mr. Dennis	Chief	Wastewater Branch	Department of Health 919 Ala Moana Blvd., Room 309 Honolulu, HI 96801	586-4294		
Health	Wong	Mr. William K.C.	Chief	Safe Drinking Water Branch	Department of Health 919 Ala Moana Blvd., Room 308 Honolulu, HI 96813	586-4790		
Hickam AFB	Blake	Lt. Mark			15 CES/CEVP 75 H Street Hickam AFB, HI 96853-5233	449-7514		
Hickam AFB	Brown	Col. Bruce			15 ABW/CC 800 Scott Circle Hickam AFB, HI 96853-5328			
Hickam AFB	Cole	Capt. Craig			15 CES/CECP 75 H Street Hickam AFB, HI 96853-5233	449-1385	Yes; @ Scoping Mtg	Yes
Hickam AFB	Davis	Major Joe			15 ABW/PAI 800 Scott Circle Hickam AFB, HI 96853-5328	449-6662		
Hickam AFB	Director of Housing				15 CES/CEH 900 Hangar Avenue Hickam AFB, HI 96853-5233	-		
Hickam AFB	Hooper	Major ?			10 Worchester Ave Hickam AFB, HI 96818	449-0477		
Hickam AFB	McGhee	Michael F.	Chief Environmental Flight		15 CES/CEB 75 H Street Hickam AFB, HI 96853-5233	449-1584		
Hickam AFB	Milke	Ryan			15 ABW/PAI 800 Scott Circle Hickam AFB, HI 96853-5328	449-6662		
Hickam AFB	Szatanek	Capt. Jeff			HQ PACAF/CEVP 25 E Street Suite D-306 Hickam AFB, HI 96853-5412	449-2791		
Hickam AFB	Vaughn	David S.			HQ PACAF/CEVP 25 E Street Suite D-306 Hickam AFB, HI 96853-5412		Attended scoping mtg.	Yes
Hickam Harbor	Zak	Stephan	Harbor Master		15 SVS/SVRO 900 Hangar Ave. Hickam AFB, HI 96853-5426	449-5215		
Land and Natural Resources	Devick	Mr. William	Acting Administrator	Aquatic Resources Division	Dept. of Land & Natural Resources 1151 Punchbowl Street, Room 330 Honolulu, HI 96813	587-0100		
Land and Natural Resources	Hibbard, PHD	Don	Director	State Historic Preservation Division	Dept. of Land & Natural Resources 33 South King Street, 6th Floor Honolulu, HI 96813	587-0047		
Land and Natural Resources	Monden	Mr. Andrew		Water & Development Branch	Dpet. of Land & Natural Resources P.O. Box 621 Honolulu, HI 96809	587-0230		
Land and Natural Resources	Uchida	Mr. Dean	Administrator	Land Division	Dept. of Land & Natural Resources 1151 Punchbowl Street, Room 202 Honolulu, HI 96809	587-0377		
Land and Natural Resources	Wilson	Mr. Michael D.	Chair		Department of Land & Natural Resources State of Hawaii P.O. Box 621 Honolulu, HI 96809	587-0404		

Organization/ Dept.	Addressee (last name)	Addressee (first name)	Title	Division	Address	Phone number	Comments received?	Receive DEIS/FEIS?
Land Utilization	Onishi	Mr. Patrick	Director		Department of Land Utilization City & County of Honolulu 650 South King Street Honolulu, HI 96813	523-4432		
Library				Ewa Beach Public School Library	91-950 North Road Ewa Beach, HI 96706	689-8391		
Library				Pearl City Public Library	1138 Waimano Home Road Pearl City, HI 96782	453-6566		
Library	Spencer	Ms. Caroline	Director	Hawaii State Library	478 South King Street Honolulu, HI 96813	586-3555		
Mamala Bay Study Commision					Mamala Bay Study Commission 900 Fort Street Mall, Suite 1300 Honolulu, HI 96813			
MK Engineers, Ltd.	Uyeda	Paul			MK Engineers, Ltd. 286 Kalihi Street Honolulu, HI 96819	848-8622		
Navy	Christopher	Greg			U.S. Naval Station Box 8 Code 31 Pearl Harbor, HI 96860-6000	474-1168		
Navy	Commander				Naval Base Pearl Harbor Box 110 Pearl Harbor, HI 96860-5020 ATTN: Clyde Yokota			
Navy	Commanding Officer				U.S. Naval Station Box 21 Pearl Harbor, HI 96860-6000 ATTN: Lt. J.G. Bain	474-8190		
Navy	Geddie	John			8040 Bellamah Ct. NE Albuquerque, NM 87110			

Organization/ Dept.	Addressee (last name)	Addressee (first name)	Title	Division	Address	Phone number	Comments received?	Receive DEIS/FEIS?
Navy	Hirano	Wesley			Code 203WH Naval Station Pearl Harbor Pearl Harbor, HI 96860	471-3460		
Navy	Kam	Donald	Staff Civil Engineer		Code 21DK Naval Station Pearl Harbor Pearl Harbor, HI 96860	474-8190		
Navy	Roome	William H.	Environmental Public Affairs Officer		Naval Base Pearl Harbor Pearl Harbor, HI 96860	471-3324 474-2328 (fax)		
Navy	Stokes	Lt. Commander			Code 30 Port Operations Naval Station Pearl Harbor Pearl Harbor, HI 96860	474-0418		
Navy	Takeuchi	Jeff			Code 612 US Naval Submarine Base Pearl Harbor, HI 96860	471-2571		
Navy Public Works Center	Eisenpress	Nate	Staff Civil Engineer		U.S. Navy Public Works Center Code 22 Pearl Harbor, HI 96860			
Navy Public Works Center	Higuchi	Joanne		Environmental Compliance	U.S. Navy Public Works Center Code 09E Pearl Harbor, HI 96860		Attended scoping mtg.	No
Navy Public Works Center	Iha	Preston		Utilities Department	U.S. Navy Public Works Center Code 640 Pearl Harbor, HI 96860	471-9703	Attended scoping mtg.	
Navy Public Works Center	Puana	Reggie		Utilities Department	U.S. Navy Public Works Center Code 640 Pearl Harbor, HI 96860			
Navy Public Works Center	Steel	Francis	Staff Civil Engineer		U.S. Navy Public Works Center Code 22 Pearl Harbor, HI 96860			

Organization/ Dept.	Addressee (last name)	Addressee (first name)	Title	Division	Address	Phone number	Comments received?	Receive DEIS/FEIS?
Neighborhood Board	Miura	Mr. Mike		Aiea Neighborhood Board	99-656 Aliipoe Drive Aiea, HI 96701	486-6003		
Neighborhood Board	Souza	Mr. Jerry		Pearl City Neighborhood Board	P.O. Box 19 Pearl City, HI 96782	456-3088		
Neighborhood Board	Tanimoto	Mr. Grant		Aliamanu Neighborhood Board	3447 Ala Haukulu Street Honolulu, HI 96818			
Office of the Mayor	Harris	Mayor Jeremy			Office of the Mayor City & County of Honolulu City Hall 530 South King Street, Rm 300 Honolulu, HI 96813	523-4385		
PACDIV	Ige	Ed			Code 5014 PACNAVFACENGCOM Pearl Harbor, HI 96860-7300	474-4870		
PACDIV	Kaku	Melvin			Code 23 Envrionmental Planning Division PACNAVFACENGCOM Pearl Harbor, HI 96860-7300		Attended scoping mtg.	
PACDIV	Kasaoka	Gary			Code 231GK Environmental Planning Division PACNAVFACENGCOM Pearl Harbor, HI 96860-7300		Attended scoping mtg.	
PACDIV	Koga	Mike			Code 048 PACNAVFACENGCOM Pearl Harbor, HI 96860-7300			
PACDIV	Lackey	Janet			Code 00D Public Affairs Office PACNAVFACENGCOM Pearl Harbor, HI 96860-7300	471-0774 474-4544 (fax)	Attended scoping mtg.	
PACDIV	Matoi	Shirley			Code 405 PACNAVFACENGCOM Pearl Harbor, HI 96860-7300			
PACDIV	Poentis	Aaron			Code 1811 PACNAVFACENGCOM Pearl Harbor, HI 96860-7300	471-2818	Attended scoping mtg.	
PACDIV	Sullivan, Esq.	Paul M.			PACNAVFACENGCOM Pearl Harbor, HI 96860-7300	471-8460	Attended scoping mtg.	No
PACDIV	Sumida	Karen			Code ? PACNAVFACENGCOM Pearl Harbor HI 96860-7300		Attended scoping mtg.	No
PACDIV	Wong	Orrin			Code 1811 PACNAVFACENGCOM Pearl Harbor, HI 96860-7300			
Planning Department	Soon	Ms. Cheryl	Chief Planning Officer		Planning Department City & County of Honolulu 650 South King Street, 8th Floor Honolulu, HI 96813	523-4713		
Public	Baba	Keith & Suzanne			1640 Hooheke Street Pearl City, HI 96782		Yes; @ scoping mtg.	No
Public	Clark	John			P.O. Box 25277 Honolulu, HI 96825		Attended scoping mtg.	Yes
Public	Enisley	Denise			710 Lunalilo St. #504 Honolulu, HI 96813		Attended scoping mtg.	No
Public (SSFM sub)	Grace	Robert			1939 Kahela Drive Honolulu, HI 96822		Attended scoping mtg.	Yes
Public	Jenson	Sidney			6940 Kehampton Farmington, Utah 84015		Attended scoping mtg	Yes
Public	Okawa	Dwight			1357 Halekoa Drive Honolulu, HI 96821		Attended scoping mtg.	Yes.

Organization/ Dept.	Addressee (last name)	Addressee (first name)	Title	Division	Address	Phone number	Comments received?	Receive DEIS/FEIS?
Public	Taguchi	Ben			P.O. Box 185 Honolulu, HI 96810		Attended scoping mtg.	Yes
Public	Tasaka	Rossyn			1411 Ala Leleu St. Honolulu, HI 96818		Attended scoping mtg.	—
Public	Terri	Marie			P.O. Box 4932 Kaneohe, HI 96744		Attended scoping mtg.	Yes
Public Interest				Blue Ocean Preservation Society	P.O. Box 1850 Kihei, HI 96753			
Public Interest				Conservation Council for Hawaii	P.O. Box 2923 Honolulu, HI 96802	521-2302		
Public Interest				Earthtrust	Aikahi Park Shopping Center 25 Kaneohe Bay Dr., Suite 511 Kailua, HI 96734	254-2866		
Public Interest				Greenpeace Foundation of Hawaii	P.O. Box 277 208 Kihei, HI 96753			
Public Interest				Hawaii Chapter American Fisheries Society	861 Hokulani Street Honolulu, HI 96825			
Public Interest				Hawaii Office Natural Resources Defense Council	212 Merchant Street, Suite 203 Honolulu, HI 96813			
Public Interest				Hawaii's Thousand Friends	305 Nahani Street, Suite 282 Kailua, HI 96734	262-0682		
Public Interest				Life of the Land	1111 Bishop Street, Suite 511 Honolulu, HI 96813	533-3454		
Public Interest				Native Hawaiian Legal Corporation	1164 Bishop Street, Suite 1205 Honolulu, HI 96813	521-2302		

Organization/ Dept.	Addressee (last name)	Addressee (first name)	Title	Division	Address	Phone number	Comments received?	Receive DEIS/FEIS?
Public Interest				Sierra Club Legal Defense Fund, Inc.	223 South King Street, 4th Floor Honolulu, HI 96813	599-2436 521-6841 (fax)		
Public Interest				Sierra Club Hawaii Chapter	1111 Bishop Street, Suite 511 Honolulu, HI 96813	538-6616		
Public Interest				The Ocean Recreation Council of Hawaii	P.O. Box 661 Kailua, HI 96734			
Public Interest	Cayan	Ms. Phyllis	Chairperson	Oahu Burial Committee	98-295 Ualo Street, Room X4 Aiea, HI 96701			
Public Interest	Kubota	Stephen T.		Ahupua'a Action Alliance	44-281 Mikiola Dr. Kaneohe, HI 96744		Yes; @ scoping mtg.	Yes
Public Interest	Madlener	Fred		Hawaii's Thousand Friends	46-196 Yacht Club St. Kaneohe, HI 96744		Yes; @ scoping mtg	Yes
Public Interest	Nihipali	Mr. Kunani		Hui Malama I Na Kupuna O Hawaii Nei	P.O. Box 190 Haleiwa, HI 96712-0190			
Public Interest	Norris	Mr. Jerry	Executive Director	Pacific Basin Development Council	711 Kapiolani Blvd., Suite 1075 Honolulu, HI 96813	596-7229		
Public Interest	Olds	Ms. Clara		Save Our Bays & Beaches	150 Hamakua Drive, Suite 727 Honolulu, HI 96834	262-7622		
Public Interest	Reid	Mr. Shawn		Surfrider Foundation	66-590 Kamehameha Hwy., Suite 727 Haleiwa, HI 96712			
Public Interest	Reppun	Mr. John		Hui Malama Aina O Koolau	47-200 Waihee Road Kaneohe, HI 96744			
Public Interest	Yardley	Toni		Women of Hale O' Papa	44-114 Keaalau Pl. Kaneohe, HI 96744		Yes; @ scoping mtg.	Yes

Organization/ Dept.	Addressee (last name)	Addressee (first name)	Title	Division	Address	Phone number	Comments received?	Receive DEIS/FEIS?
Public Works	Sprague	Dr. Kenneth	Director		Department of Public Works City & County of Honolulu 650 South King Street, 11th Floor Honolulu, HI 96813	523-4341		
ROICC MIDPAC	Pang	Hiram			ROICC MIDPAC Box 104 Pearl Harbor, HI 96860	471-2221		
Sea Engineering	Rocheleau	Bob			Sea Engineering Makai Research Pier Waimanalo, HI 96795	259-7966 259-8143 (fax)		
State Capitol	Cachola	Representative Romy M.		House	State Capitol 415 S. Beretania Street Honolulu, HI 96813	586-6110		
State Capitol	Graulty	Senator Rey		Senate	State Capitol 415 S. Beretania Street Honolulu, HI 96813	586-6670		
State Capitol	Ige	Senator David Y.		Senate	State Capitol 415 S. Beretania Street Honolulu, HI 96813	586-6230		
State Capitol	Iwase	Senator Randall Y.		Senate	State Capitol 415 S. Beretania Street Honolulu, HI 96813	586-670		
State Capitol	Mizuguchi	Senator Norman		Senate	State Capitol 415 S. Beretania Street Honolulu, HI 96813	586-6870		
State Capitol	Pepper	Representative Lennard J.		House	State Capitol 415 S. Beretania Street Honolulu, HI 96813	586-6320	Yes; @ scoping mtg	Yes
State Capitol	Takumi	Representative Roy M.		House	State Capitol 415 S. Beretania Street Honolulu, HI 96813	586-6170		

Organization/ Dept.	Addressee (last name)	Addressee (first name)	Title	Division	Address	Phone number	Comments received?	Receive DEIS/FEIS?
State Planning	Pai	Mr. Gregory	Director		Office of State Planning State of Hawaii 415 S. Beretania Street, Room 409 Honolulu, HI 96813	587-2846		
Transportation	Fujikawa	Mr. Thomas	Chief	Harbors Division	Department of Transportation 79 S. Nimitz Highway Honolulu, HI 96813	587-1930		
U.S. Department of Agriculture	Kaneshiro	Mr. Kenneth M.	State Conservationist	Natural Resources Conservation Service	U.S. Department of Agriculture P.O. Box 50004 Honolulu, HI 96850-0001	541-2600		
U.S. Dept. of the Interior	Meyer	Mr. William	District Chief	Geological Survey Water Resources Div.	U.S. Dept. of the Interior 677 Ala Moana Blvd., Suite 415 Honolulu, HI 96813	522-8290		
U.S. Dept. of the Interior	Smith	Mr. Robert	Ecoregion Manager	Fish & Wildlife Service	U.S. Dept. of the Interior P.O. Box 50156 Honolulu, HI 96850	541-2749		
U.S. EPA	Marcus	Ms. Felicia	Regional Administrator	U.S. Environmental Protection Agency, Region IX	75 Hawthorne Street San Francisco, CA 94105			
U.S. EPA	Tsuhako	Ms. Vicki H.	Manager	Pacific Islands Contact Office	U.S. Environmental Protection Agency 300 Ala Moana Blvd., Room 5124 Honolulu, HI 96813	541-2710 541-2712 (fax)		
Univeristy of Hawaii	Harrison PHD	John T.	Director	Environmental Center	University of Hawaii 2250 Campus Road, Crawford 317 Honolulu, HI 96822	956-7361		
Univeristy of Hawaii	Helsley	Dr. Charles E.	Director	Sea Grant College Program	University of Hawaii 1000 Pope Road, MSB, Room 220 Honolulu, HI 96822	956-7031		

Organization/ Dept.	Addressee (last name)	Addressee (first name)	Title	Division	Address	Phone number	Comments received?	Receive DEIS/FEIS?
University of Hawaii	Fujioka PHD	Roger S.	Director	Water Resources Reseach Center	University of Hawaii 2540 Dole Street, Holmes Hall 283 Honolulu, HI 96822	956-7847		
University of Hawaii	Maynard	Dr. Sherwood	Director	Marine Option Program	University of Hawaii 1000 Pope Road, Room 229 Honolulu, HI 96822	956-8433		
Wastewater Management	Limtiaco	Mr. Felix B.	Director		Department of Wastewater Management City & County of Honolulu 650 South King Street, 3rd Floor Honolulu, HI 96813	527-6663		

Appendix II-c

Notice of Intent Announcement

Honolulu-Star Bulletin

NOTICE OF INTENT
PREPARATION OF EIS

Pursuant to Section 102(2)(c) of the National Environmental Policy Act (NEPA) of 1969, as implemented by the Council on Environmental Quality regulations (40 CFR Parts 1500-1508), the Navy announces that it will prepare an EIS for the proposed construction of a replacement outfall for the existing wastewater treatment plan at Fort Kamehameha, Pearl Harbor, Oahu, Hawaii. The action consists of constructing a 12,000-foot long, 42-inch diameter wastewater outfall extension that will discharge through a multiport diffuser at a water depth of between 70 and 150 feet into Class A, open, coastal, marine waters. The proposed outfall will reduce nutrient mass loading in the Pearl Harbor estuary. The action is consistent with the State of Hawaii's management plan for the Pearl Harbor estuary, pursuant to Section 304(l) of the Clean Water Act. The existing outfall will be retained for emergency operations.

Construction activities include excavating an underwater trench across the offshore limestone reef and in the Pearl Harbor entrance channel, installing pipe in the trench, and covering the pipeline with protective material. Construction equipment will be staged in the immediate vicinity of the treatment plant. Approximately 30,000 cubic yards of excavated material will be disposed at an approved offshore dredge spoil discharge site. In shallow water, the top of the outfall protective concrete mats will be approximately even with or just below the existing bottom contour. In deep water, the protective layer will be one meter below the design maintenance dredge depth. Construction activities will occur over a period of approximately 18 months.

The Navy is initiating a scoping process to identify significant issues for study in the EIS and to identify and notify parties interested in and affected by the proposed action. Interested parties should take this opportunity to present environmental concerns and feasible alternatives that need to be addressed in the EIS.

Two public scoping meetings will be held: (1) October 1, 1996, 7:00 - 10:00 pm, Washington Intermediate School, 1633 South King Street, Honolulu, and (2) October 2, 1996, 7:00 - 10:00 pm, Makalapa Elementary School, 4435 Salt Lake Boulevard, Honolulu. Interested parties are invited to provide written and/or oral comments at the public meetings. Mailed written statements must be received no later than October 18, 1996 by Mr. Melvin Kaku (Code 23), Pacific Division, Naval Facilities Engineering Command, Pearl Harbor, HI 96860-7300, telephone (808) 471-9338; fax (808) 474-4890.

(Hon. S.-B.: Sept. 20, 1996) (SB-5844)

Honolulu Advertiser

NOTICE OF INTENT
PREPARATION OF EIS

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(Hon. Adv.: Sept. 22, 1996) (A-41146)

Appendix II-d

Scoping Meeting Attendance Records

ATTENDANCE RECORD - PLEASE PRINT LEGIBLY

Public Hearing - DEIS for Proposed Construction of a Replacement Outfall for the Wastewater Treatment Plant at Fort Kamehameha, Pearl Harbor, Oahu, Hawaii

October 1, 1996, 7:00 p.m., Washington Intermediate School Cafeteria

~~IF YOU PLAN TO SPEAK, SIGN IN HERE AND THEN COMPLETE AND SUBMIT A "SPEAKER SIGN-IN FORM."~~

NAME	COMPLETE MAILING ADDRESS (INCLUDING ZIP CODE)	REPRESENTING	DO YOU PLAN TO SPEAK? YES	NO	DO YOU WISH TO RECEIVE A COPY OF THE DEIS/FEIS? YES	NO
FRED MADLENER	Hawaii's Thousand Friends	46-196 yacht club St. Kaneohe HI 96744	✓		✓	
ROSSLYN TASAKA	1411 ALA LELEA ST. HON HI 96818			✓		
DWIGHT OKAWA	1357 HALEKOA DR	—		✓	✓	
TRESTON IHA	1228 KALANIKI ST. 96822	—		✓		
R. A. Grace	1939 Kahela Drive	—		✓	✓	
B. Tracewitt	PO Box 185 HNL 96810	—		✓	✓	
STEPHEN T. KUBOTA	44-281 Mikiola Dr. Kaneohe 96744	Ahupuaa Action Alliance	✓		✓	
Toni Auld Yardley	44-114 Keaalau Pl. Kaneohe 96744	Women of Hale O Papa	✓		✓	
John Clark	P.O. Box 25277 96825	—		✓	✓	

ATTENDANCE RECORD - PLEASE PRINT LEGIBLY

Public Hearing - DEIS for Proposed Construction of a Replacement Outfall for the Wastewater Treatment Plant at Fort Kamehameha, Pearl Harbor, Oahu, Hawaii

October 1, 1996, 7:00 p.m., Washington Intermediate School Cafeteria

~~IF YOU PLAN TO SPEAK, SIGN IN HERE AND THEN COMPLETE AND SUBMIT A "SPEAKER SIGN-IN FORM."~~

NAME	COMPLETE MAILING ADDRESS (INCLUDING ZIP CODE)	REPRESENTING	DO YOU PLAN TO SPEAK? YES	NO	DO YOU WISH TO RECEIVE A COPY OF THE DEIS/FEIS? YES	NO
Denise Ensley	710 Lunalilo St #504 Hono Hi			✓		✓
Joanne Higuchi	94-344 Hakamoa St. Mil., HI			✓		✓
MARIE TERRI	PO BOX 4932 KANEOHE HI 96744			✓	✓	
Karen Sumida	PACNAVFACENGCOM 96860-7300	U.S. Navy		✓		✓
Paul Sullivan	PACDIV	US Navy		✓		✓

ATTENDANCE RECORD - PLEASE PRINT LEGIBLY

Public Hearing - DEIS for Proposed Construction of a Replacement Outfall for the Wastewater Treatment Plant at Fort Kamehameha, Pearl Harbor, Oahu, Hawaii

October 2, 1996, 7:00 p.m., Makalapa Elementary School Cafeteria

~~IF YOU PLAN TO SPEAK, SIGN IN HERE AND THEN COMPLETE AND SUBMIT A "SPEAKER SIGN-IN FORM."~~

NAME	COMPLETE MAILING ADDRESS (INCLUDING ZIP CODE)	REPRESENTING	DO YOU PLAN TO SPEAK? YES	NO	DO YOU WISH TO RECEIVE A COPY OF THE DEIS/FEIS? YES	NO
RONALD C. COLE	75 H Street Hickam AFB HI 96853-5233	15 CES/CECP		X	X	
LENNARD J. PEPPER	STATE CAPITOL HON 96813	STATE HOUSE DIST 32		X	X	
Suzanne Baba	1643 Hoolehe St.	public		X		X
Keith Baba	same	public		X		X
DAVID S. VAUGHN	25 E ST STE D-306 HICKAM AFB 96853-5412	HQ PACAF/CEVP		X	X	
SIDNEY JENSON	6140KEHAMPTON Farmington, Utah 84025	MYSELF		X	X	
Aaron Poentis	PACNAVFACENGCOM - 1811AP	PACNAVFACENGCOM		X		

Appendix II-e

Scoping Meeting Group Memories

ENVIRONMENTAL IMPACT STATEMENT FOR PROPOSED OUTFALL REPLACEMENT FOR THE WASTEWATER TREATMENT PLANT AT FORT KAMEHAMEHA, PEARL HARBOR, OAHU, HAWAII

PUBLIC SCOPING MEETING

OCTOBER 1, 1996

7:00 p.m.
Washington Intermediate School
1633 South King Street
Honolulu, HI

GROUP MEMORY

The meeting began with a short presentation by the consultant regarding the various options under consideration for the proposed outfall replacement at the Wastewater Treatment Plant (WWTP) at Fort Kamehameha, Pearl Harbor, Hawaii. Four alternatives were discussed which included: (1) the Proposed Action (construction of a new outfall outside the Pearl Harbor Estuary in the open ocean); (2) the reuse of the secondary treated effluent for irrigation; (3) the injection of the treated effluent into the groundwater; and (4) the No Action alternative, or the continued use of the existing outfall in the Pearl Harbor Estuary. A handout was provided that described each alternative.

The attendees were then asked to identify the issues and concerns from their point of view that needed to be addressed in the Environmental Impact Statement. The following comments were received:

- What will be the capacity of the pipes?
- What are the estimated costs associated with the alternatives?
- Mamala Bay has had a lot of problems. It would be worthwhile to review the Mamala Bay study.
  - There are surfacing sewage plumes.
  - Sand Island outfall did not go below the thermocline of 300 feet (depth) which would prevent surfacing sewage plumes.
- Length of outfall needs to be extended due to sloping ground.
- Nature and composition of discharge needs to be considered.
- Need for pretreatment of industrial wastewater.
- Not in favor of alternative that crosses the reef. Need to minimize reef impacts.
- Reef impacts will be an issue for OHA and Native Hawaiian rights. May be ceded lands.
- Need to consult with EPA on the above issue. The Department of Health and EPA do not look favorably upon injection wells. They plug up, may have adverse effects on groundwater, and we don't know where effluent plume may emerge.
- Reuse option is attractive. Testimony in Waiahole/Waikane case regarding the reuse of water as an alternative to discharge should be explored further to preserve potable resources.
- Reuse alternative should be encouraged.
  - Economic and social costs involved need to be considered.
  - Review California water reuse model since they are making enough money to make the plant self-sufficient
- Area is within ahupua'a of Halawa.
- Coastline of the ahupua'a - currently in process of establishing a cultural preservation plan for Halawa Valley.
- How will the issue of human burials be treated? What will become of the iwi? This needs to be considered a top priority.
- Cultural sensitivity is important. This is a sacred area. Location needs to be respected. Need to acknowledge this entrance to Pu'uloa and mouth of Halawa. The EIS needs to address cultural issues with sensitivity and deal with priorities.
- There will some objection to the disruption of the reef.
- Include cultural specialist(s), in addition to an archaeologist, to help identify cultural resources. Need to contact this person/group as the project moves forward. This person/group can provide advice and help.
- Women of Hale o'papa are serving in a cultural capacity for the ahupua'a and can be of assistance to this project. There needs to be coordination with this group.
- Ahupu'a Action Alliance's focus is on marine biodiversity.
  - Alliance advocates the use of the traditional ahupua'a.
  - The entire ahupua'a should be brought into the scope of the EIS.
  - Traditional and customary rights are constitutionally protected - need to address this.
- Need a demographic study of reef use.
- Use the ahupua'a since this approach focuses on integrated resource management. The EIS needs to look at this perspective.
- Need to consider the entire community surrounding Pearl Harbor and the impacts to these outlying areas (especially as related to biodiversity).
- Reuse should be the first option. The Navy should anticipate opposition from native Hawaiian and environmental groups -- reuse could be used as an opportunity to move the effort forward.
- Reuse could be incorporated with the Superfund Clean Up.
- Navy should extend a hand in creating a "partnership" with the community.
- Impacts of downsizing sugar communities should be examined. This reuse option may create options for this. Need to look at the positive economic values.
- Commend the Navy for extending the outfall. The main thrust should be for reuse since Pearl Harbor aquifer is overworked and will likely result in a water shortage in the future.
- Need to look at the wetlands/wildlife preserves and barriers around Pearl Harbor and consider creating additional wetlands.
- Establish vegetative buffers around Pearl Harbor and irrigate with effluent. Will act as sediment barriers.
- Look at Ala Wai cleanup (i.e., residues from vehicular traffic).
  - Regular washing of roads can help to breakdown residues instead of a onetime impact.
  - This can also provide an economic opportunity and may serve as a model for a paradigm shift.
- Will there be chlorinated sewage going out of the pipes?
  - Chlorine is destructive and would interfere with reuse.
  - Consider ultraviolet disinfection since it would allow for multiple uses.
  - Explore Water Resource Research (UH) study on ultraviolet.

ENVIRONMENTAL IMPACT STATEMENT FOR PROPOSED OUTFALL REPLACEMENT FOR THE WASTEWATER TREATMENT PLANT AT FORT KAMEHAMEHA, PEARL HARBOR, OAHU, HAWAII

PUBLIC SCOPING MEETING

OCTOBER 2, 1996

7:00 p.m.
Makalapa Elementary School
1633 South King Street
Honolulu, HI

GROUP MEMORY

The meeting began with a short presentation by the consultant regarding the various options under consideration for the proposed outfall replacement at the Wastewater Treatment Plant (WWTP) at Fort Kamehameha, Pearl Harbor, Hawaii. Four alternatives were discussed which included: (1) the Proposed Action (construction of a new outfall outside the Pearl Harbor Estuary in the open ocean); (2) the reuse of the secondary treated effluent for irrigation; (3) the injection of the treated effluent into the groundwater; and (4) the No Action alternative, or the continued use of the existing outfall in the Pearl Harbor Estuary. A handout was provided that described each alternative.

The attendees were then asked to identify the issues and concerns from their point of view that needed to be addressed in the Environmental Impact Statement. The following comments were received:

- Impacts on recreational resources along shoreline and entire harbor.
- How does the current go into Mamala Bay? Will it be carrying effluent into the Bay?
- What will keep the pipes from becoming clogged? Design and maintenance of the pipes needs to be addressed.
- Concern regarding construction impacts: Where will the construction sites and laydown areas be located?
- What will be the impacts on the reef?
- Impacts on wetlands/shoreline and the neighboring residential areas.
- Opportunity for reuse of effluent. What will be the cost to lay piping and reduce the salinity of the effluent?
- Who will make the final decision?
- There needs to be a cost comparison within the EIS.
- The Alignment Alternative 1 is better for the reef.
  - Inshore reef is essentially dead.
  - Need to survey the reef environment and select the alternative which does the least damage.
- Movement of the outfall further out may have a positive effect on the reef.

Appendix II-f

Written Scoping Comments

96-1029

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
DIVISION OF AQUATIC RESOURCES
1151 PUNCHBOWL STREET
HONOLULU, HAWAII 96813

October 14, 1996

Mr. Melvin Kaku (Code 23)
Pacific Division
Naval Facilities Engineering
Pearl Harbor, Hawaii 96860-7300

Dear Mr. Kaku:

Subject: Comments on the Proposed Replacement Outfall for the Wastewator Treatment Plant at Fort Kamehameha

We are concerned about the project's long and short term impacts on aquatic resources. The upcoming EIS should contain 1) detail information on the affected underwater habitats with each of the "several outfall alignments" being considered; 2) specific impacts on aquatic resources if the "upland disposal of wastewater effluent, either by reuse or disposal through underground injection wells" alternative is selected; 3) potential impacts from each of the three construction method options (either barges, a temporary berm, or directional drilling) proposed; 4) project's impact on area resource users (fishermen, divers, etc.); 5) affects from the long term turbidity and siltation in the vicinity of the project on aquatic habitat and resources; 6) impacts on endangered or threaten marine species (humpback whales, monk seals, and sea turtles); 7) changes to the present ecology as the "proposed outfall will reduce nutrient mass loading on the Pearl Harbor estuary"; and 8) mitigation measures (i.e. coral transplanting, placement of artificial habitats, etc.) for habitat and resources disturbed, damaged or destroyed.

Thank you for the opportunity to provide our comments on this important matter. We would appreciate an opportunity to review the upcoming EIS for the proposed project.

Sincerely,

William S. Devick

William S. Devick, Acting Administrator
Division of Aquatic Resources

United States Department of the Interior

FISH AND WILDLIFE SERVICE
PACIFIC ISLANDS ECOREGION
300 ALA MOANA BOULEVARD, ROOM 3108
BOX 50088
HONOLULU, HAWAII 96850
PHONE: (808) 541-3441 FAX: (808) 541-3470

In Reply Refer To: AAP

OCT 2 5 1996

Mr. Frederick J. Minato
Environmental Planning Division
Department of the Navy
Pacific Division Naval Facilities Engineering Command
Pearl Harbor, Hawaii 96860-7300

Re: Notice of Intent to prepare an Environmental Impact Statement for the Construction of a Replacement Outfall for the Wastewater Treatment Plant at Fort Kamehameha, Pearl Harbor, Hawaii

Dear Mr. Minato:

The U.S. Fish and Wildlife Service (Service) has reviewed the Notice of Intent (NOI) to prepare an Environmental Impact Statement (EIS) for the construction of a replacement outfall pipe at the Fort Kamehameha Wastewater Treatment Plant, Pearl Harbor, Oahu, Hawaii. The project sponsor is the Department of the Navy. This letter has been prepared under the authority of and in accordance with provisions of the National Environmental Policy Act of 1969 [42 U.S.C. 4321 *et seq.*; 83 Stat. 852], as amended, the Fish and Wildlife Coordination Act of 1934 [16 U.S.C. 661 *et seq.*; 48 Stat. 401], as amended, the Endangered Species Act of 1973 [16 U.S.C. 1531 *et seq.*; 87 Stat. 884], as amended, and other authorities mandating Service concern for environmental values. Based on these authorities, the Service offers the following comments for your consideration.

The proposed action involves replacing an existing outfall pipe with a new pipe that is 12,000 feet long and 42 inches in diameter, which will discharge effluent through a multiport diffuser at water depths between 70 and 150 feet. The proposed outfall will be covered with protective material and placed in an underwater trench. The outfall pipe will be assembled on land, floated out to the outfall alignment, supported by gravel beds in the trench, and capped with concrete mates or tremie concrete. Installation of a temporary earthen berm for equipment access is anticipated, and one or more barges will be involved during construction in the channel. Approximately 30,000 cubic yards of substrate will be dredged for the underwater trench, which will run across a shallow, fringing reef flat and into the Pearl Harbor entrance channel. Disposal of the dredged material will occur at an approved offshore dredged material discharge site.

NOI to Prepare EIS
Replacement of an Existing Outfall Pipe
Pearl Harbor, Oahu, Hawaii

The purpose of the EIS is to evaluate potential environmental impacts associated with the proposed action within the affected area and to identify specific measures to avoid or minimize potential significant impacts. The Service recommends that the Draft EIS address construction-related impacts to fish and wildlife resources and habitats associated with each outfall design, alignment alternative, and associated construction methodology. The Service recommends that particular attention be given in the Draft EIS to addressing impacts on endangered and threatened species, migratory fishes and shorebirds, and maintenance of water quality conditions in accordance with Hawaii water quality standards.

Migratory shorebirds, such as ruddy turnstones (*Arenaria interpres*) and Pacific golden plovers (*Pluvialis fulva*), federally threatened green sea turtles (*Chelonia mydas*) and federally endangered Hawaiian monk seals (*Monachus schauinslandi*) may occur on the mudflat and along the shoreline within the project vicinity. However, sea turtles are not known to nest in this area. We recommend that the applicant contact the National Marine Fisheries Service for further information on sea turtles and marine mammals.

Regarding placement of the proposed outfall, the Service recommends that the applicant consider bolting the outfall to the substrate rather than trenching to minimize project-related adverse impacts to fish and wildlife resources and habitats. However, if dredging of an underwater trench is necessary, we recommend that the applicant back fill the trench with the original dredged material to restore potential habitat. Also, provisions should be made for the temporary storage or dewatering of the dredged material, if appropriate, behind an impermeable berm above the influence of the tides.

The Service appreciates the opportunity to provide comments on the NOI, and we look forward to receiving a copy of the Draft EIS for review. If you have questions regarding these comments, please contact Fish and Wildlife Biologist Arlene Pangelinan at 808/541-3441.

Sincerely,

for Brooks Harper
Field Supervisor
Ecological Services

CC: NMFS - PAO, Honolulu
EPA - Region IX, San Francisco
DAR, Hawaii
CZMP, Hawaii
CWB, Hawaii

STATE OF HAWAII
DEPARTMENT OF HEALTH
P.O. BOX 3378
HONOLULU, HAWAII 96801

LAWRENCE MIIKE
DIRECTOR OF HEALTH

In reply, please refer to

October 28, 1996

96-157/epo

Mr. Frederick J. Minato
Acting Director
Environmental Planning Division
Naval Facilities Engineering Command
Department of the Navy
Pearl Harbor, Hawaii 96860-7300

Dear Mr. Minato:

Subject: Notice of Intent to Prepare
Environmental Impact Statement
Construction of Replacement Outfall
Fort Kamehameha Wastewater Treatment Plant
Pearl Harbor, Hawaii

Thank you for notifying us of your proposed project and allowing us to comment on the areas that the Environmental Impact Statement should address. Our comments are as follows:

Water Pollution

1. You should contact the Army Corps of Engineers to identify whether a Federal permit (including a Department of Army permit) is required for this project. A Section 401 Water Quality Certification is required from the Department of Health for "any applicant for Federal license or permit to conduct any activity including, but not limited to, the construction or operation of facilities, which may result in any discharge into the navigable waters...", pursuant to Section 401(a)(1) of the Federal Water Pollution Act (commonly known as the "Clean Water Act).

2. If the project involves the following activities with discharges into state waters, a National Pollutant Discharge Elimination System (NPDES) general permit is required for each activity:

   a. Discharge of storm water runoff associated with construction activities, such as clearing and grading, for projects equal to or greater than five (5) acres of total land area;

   b. Construction dewatering effluent;
   c. Non-contact cooling water;
   d. Hydrotesting water; and
   e. Treated contaminated groundwater from underground storage tank remedial activity.

3. If there is any type of process wastewater discharge from the facility into state waters, you may be required to apply for an Individual NPDES permit.

4. Any additional mass loading on the receiving water will require the U.S. Navy to satisfy the antidegradation policies of the State. A copy of the June 3, 1987 Region 9, U.S. Environmental Protection Agency's "Guidance on Implementing the Antidegradation Provisions of 40 CFR 131.12" is attached for your information.

Should you have any questions regarding this matter, please contact Ms. Joanna L. Seto, Engineering Section of the Clean Water Branch, at 586-4309.

Wastewater Treatment

Our main concern is the proper treatment and disposal of domestic wastewater from the plant which should be addressed in the EIS.

All wastewater plans must conform to applicable provisions of the Department of Health's Administrative Rules, Chapter 11-62, "Wastewater Systems." We reserve the right to review the detailed wastewater plans for conformance to applicable rules.

Should you have any questions on this matter, please contact Ms. Lori Kajiwara of the Wastewater Branch at 586-4294.

Very truly yours,

for THOMAS E. ARIZUMI, P.E.
Chief, Environmental Management Division

Attachment

U.S. ENVIRONMENTAL PROTECTION AGENCY

Region 9

Guidance on Implementing the Antidegradation Provisions of 40 CFR 131.12

RICHARD A. CODDINGTON
Acting Director
Water Management Division

June 3, 1987
Date

PURPOSE

This document provides general program guidance for the States of Region 9 on the development of procedures for implementing State antidegradation policies. The focus of this guidance is on 40 CFR 131.12 of the water quality standards regulation (promulgated in 48 FR 51407, dated November 8, 1983) which sets out requirements to be met before any action is taken that would lower the quality of the Nation's waters.

BACKGROUND

Section 101(a) of the Clean Water Act defines the national goal of restoring and maintaining the chemical, physical and biological integrity of the Nation's waters. Section 304(a)(4) of the Clean Water Act explicitly refers to satisfaction of the antidegradation requirements of 40 CFR 131.12 prior to taking various actions which would lower water quality. 40 CFR 131.12 requires that antidegradation provisions at least as stringent as those specified in that regulation be adopted by States as part of their water quality standards.

This guidance identifies the tasks to be performed by States to implement Section 131.12 of the water quality standards regulation. Those tasks that need the development of decision criteria by the States are identified. Such criteria are necessary to define those actions which require detailed economic or water quality impact analyses. The Agency expects States to develop and document these criteria in their antidegradation implementation procedures, for review and approval by EPA regional offices. The Agency's objective is to achieve the goals of the Act through an integrated approach to eliminating water pollution which includes the consistent application of State antidegradation policies. Figure 1 lays out the decision making process of an antidegradation analysis.

Many of the procedures identified herein are already performed by States as part of their regulatory programs. Consequently, this document primarily serves to delineate, in a consistent manner, the criteria EPA Region 9 will be using to evaluate both State and EPA decisions, for compliance with 40 CFR 131.12.

TIER III WATERS - Outstanding National Resource Waters

40 CFR 131.12(a)(3) prohibits any action which would lower water quality in waters designated as Outstanding National Resource Waters (ONRWs). Examples of such waters include, but are not limited to, waters of National and State parks and wildlife refuges, and waters of exceptional recreational or ecological significance.

TIER I WATERS

40 CFR 131.12(a)(1) prohibits any action which would lower water quality below that necessary to maintain and protect existing uses. In cases where water quality is just adequate to support the propagation of fish, shell fish and wildlife and recreation in and on the water, such water quality must be maintained and protected. In cases where water quality is lower than necessary to support these uses, the requirements in Section 303(d) of the Act, 40 CFR 131.10 and other pertinent regulations must be satisfied. Guidance concerning actions affecting these waters has been published elsewhere and will not be repeated here.

TIER II WATERS - High Quality Waters

Applicability

40 CFR 131.12 establishes certain minimum requirements for States to adopt regulating actions which would lower water quality in high quality waters. These waters are defined as those in which water quality exceeds that necessary to support propagation of fish, shellfish and wildlife and recreation in and on the water. Any action which would result in, or which would permit, a lowering of water quality must be addressed in State implementation procedures. Actions covered by antidegradation provisions include, but are not limited to the following:

Permit Actions

1. Issuance/Re-issuance/Modification of NPDES permits

2. Issuance of variances (e.g. 301(h), 301(m), etc.)

3. Issuance of permits for urban runoff

4. Issuance of Section 404 permits

5. Adoption of or alteration of mixing zones

6. Relocation of discharge

7. Commencement of discharge from a new source

8. Increases in the discharge of pollutants from point sources due to:

   a. Industrial production increases

   b. Municipal growth

   c. New sources

   d. Etc.

Standards/Load Allocation Actions

1. Water quality standards revisions

2. Revision of wasteload allocations

3. Reallocation of abandoned loads

4. Section 401 certifications (for example; concerning FERC licenses, Corps' actions, etc.)

5. Section 208 or Section 303(e) approvals

6. WQM plan approvals

"Non-point Source" Actions

1. Changes in BMPs

2. Resource management plan approvals

3. Land Management (e.g. Forest) plan adoptions, certifications or approvals

4. Changes in regulated agricultural activities

5. Changes in regulated silvicultural activities

6. Changes in regulated mining activities

7. Construction and operation of roads, dams, etc.

Other Actions

1. RCRA/CERCLA actions

2. Construction grant activities

3. Other "major Federal actions" (pursuant to NEPA and the Endangered Species Act)

4. Water quantity/water rights actions which affect water quality

5. Federal actions regulated by Section 313 of the Clean Water Act

Prior to proceeding with a detailed analysis of these or similar actions, the affected water body should be assessed to determine whether or not it falls into either Tier I or Tier III. If so, actions which would lower water quality in such waters are prohibited. Otherwise, the water body should be assessed to determine the adequacy of the beneficial uses and water quality criteria designated for that water body. Adequate water quality standards must be adopted and approved for an affected water body, pursuant to 40 CFR 131 prior to allowing any action to proceed which would lower water quality in that water body.

The first step in any antidegradation analysis is to determine whether or not the proposed action will lower water quality (see Figure 1). If the action will not lower water quality, no further analysis is needed and EPA considers 40 CFR 131.12 to be satisfied. If the action could or will lower water quality, and the affected water is not a Tier I or Tier III water, then the steps to be followed to determine whether or not 40 CFR 131.12 is satisfied are described in the following sections of this guidance.

Both point and non-point sources of pollution are subject to antidegradation requirements. While point sources are generally well regulated, procedures for controlling non-point source pollution have not been as extensively defined. Cost-effective and reasonable best management practices for non-point source controls must be designed to meet water quality standards. EPA policy, first issued as SAM-32 on November 14, 1978, states that where applicable water quality standards are not met, revised or additional best management practices (BMPs) should be applied in an iterative process to improve water quality to the point that standards are attained, and that designated uses are maintained and protected. In Region 9, States generally have broad authority to regulate non-point sources. As part of their implementation methodologies, States must adopt procedures which adequately assure that non-point sources of water pollution will comply with the antidegradation requirements of 40 CFR 131.12.

Implementation Procedures

Four basic elements should be included in State implementation procedures to ensure that actions affecting water quality are consistent with the provisions of 40 CFR 131.12. They are:

- Task A – Identify Actions that Require Detailed Water Quality and Economic Impact Analyses
- Task B – Determine that Lower Water Quality Will Fully Protect Designated Uses
- Task C – Determine That Lower Water Quality is Necessary to Accommodate Important Economic or Social Development in the Area in which the Waters are Located
- Task D – Complete Intergovernmental Coordination and Public Participation

Task A – Identify Actions that Require Detailed Water Quality and Economic Impact Analyses

This task established the types of analyses required for all actions that lower water quality in Tier II waters and decision criteria that define the degree of water quality and economic analysis required.

State procedures should include three parts. First, the State should develop procedures to document the degree to which water quality exceeds that necessary to protect the uses. Ambient monitoring data can be used to provide this documentation. States must adopt procedures to assure that, where little or no data exists, adequate information will be available to determine the existing quality of the water body or bodies, which could be adversely affected by the proposed action. Such procedures should include both an assessment of existing water quality and a determination of which water quality parameters and beneficial uses are likely to be affected. These assessments and determinations could be performed either by the State or the party proposing the action in question.

Second, the State should develop procedures that quantify the extent to which water quality will be lowered as a result of the proposed action. Simple mass balance calculations or more detailed mathematic modelling, such as that contained in wasteload allocations, can provide this information. Third, the State should develop decision criteria to define the degree of water quality change that warrants detailed water quality and economic impact analyses. Decision criteria could be based on direct measures, such as an absolute or percent change in ambient concentrations of the affected parameter or indirect measures such as changes in primary productivity caused by nutrients or changes in diurnal dissolved oxygen fluctuations.

Repeated or multiple small changes in water quality (such as those resulting from actions which do not require detailed analyses) can result in significant water quality degradation. To prevent such cumulative adverse impacts, a baseline of water quality must be established for each potentially affected water body, prior to allowing any action which would lower the quality of that water. This baseline should remain fixed unless some action improves water quality. At such time, the baseline should be adjusted accordingly.

Proposed actions to lower water quality should then be evaluated with respect to the baseline and the resultant water quality change should be determined. This determination should include the cumulative impacts of all previous and proposed actions and reasonably foreseeable actions which would lower water quality below the established baseline. Should the cumulative impact of actions significantly degrade water quality, more

detailed water quality and economic impact analyses would be necessary.

In any case, whether or not water quality is significantly lowered (thus leading to an economic analysis), the State must find that any action which would lower water quality is necessary to accommodate important economic and social development. Such a finding must include, at a minimum, the following determinations:

1. That economic and social development will occur, e.g., there will be new or increased production of goods or services by the party proposing the change, population will grow in the service area of a sewage treatment plant, etc.

2. That this economic or social development requires the lowering of water quality which cannot be mitigated through reasonable means.

3. That the lower water quality does not result from inadequate wastewater treatment facilities, less-than-optimal operation of adequate treatment facilities, or failure to implement or comply with methodologies to reduce or eliminate nonpoint source pollution.

<u>Task B</u> - Determine that Lower Water Quality Will Fully Maintain and Protect Designated Uses.

All actions that could lower water quality in Tier II waters require a determination that existing uses will be fully maintained and protected. States should develop methodologies for making this determination.

Tier II waters, by definition, are those in which the water quality is better than necessary to support and maintain the biota and beneficial uses of the water. In most cases, specific numerical standards do not exist to protect these uses. Where such standards do exist, they are generally established to provide the minimum acceptable quality to protect the beneficial uses of the water. Often, such standards are established on a statewide or drainage basin-wide basis and thus may not adequately protect the biota or the uses of specific reaches. Consequently, comparing existing or projected water quality with adopted standards may not adequately define whether or not beneficial uses will be fully maintained and protected.

Water quality must also meet any applicable public health standards as well as maintain and protect the existing growth and reproduction of resident species. The water quality criteria guidance developed by EPA per §304(a) of the Clean Water Act provides a basis for this assessment. However, national water quality criteria (such as those contained in the "Gold Book") may not fully protect resident species. The criteria may not protect locally occurring species that either may not have been tested, or that have been tested, but require greater protection than the criteria provide. This determination involves a comparison of the species upon which biological testing has been completed in the criteria development documents with the species resident to the water body where water quality may be lowered. If the resident species are not adequately represented in the database, additional testing should be completed before lower water quality is allowed. Implementation methods should include procedures for making this comparison and define the circumstances (e.g., in terms of water quality change or extent of the biological testing database) that would require additional biological testing before water quality can be lowered.

Water quality criteria for dissolved oxygen or conventional and non-conventional pollutants may be subject to the same limitations and should be considered in the same way. For parameters for which no criteria guidance has been developed, biological testing or acceptable site specific criteria may be used to determine that lower water quality will fully maintain and protect designated uses.

The lowering of water quality through the discharge of conservative or persistent pollutants merits more intensive consideration by States, due to the bioacculumative potential of these pollutants. These pollutants, particularly carcinogens, which are considered to have no safe "threshold" concentration, should have more stringent antidegradation requirements established for their analysis.

Other methods of determining whether or not beneficial uses are being maintained and protected include biological assessments, such as the aquatic ecoregions procedure, or ambient toxicity testing using standardized species. In some cases, assessing the quality of water bodies on a pollutant-specific basis could prove costly, particularly for waters in which a number of

discharges are located or for complex effluents. EPA's recently developed acute and chronic toxicity methodologies for assessing the toxicity of effluents or receiving waters could provide a more comprehensive and affordable alternative.

Task C - Determine that Lower Water Quality is Necessary to Accommodate Important Economic or Social Development

Actions which the State determines in Task A to significantly lower water quality require a determination that such actions are necessary for important economic or social development. 40 CFR 131.12(a)(2) and the August 1985 "Questions and Answers on Antidegradation", give general guidance on how to make this determination. Explicit criteria defining "important economic or social development" have purposely not been developed by EPA Headquarters, because of the varying environmental, economic and social conditions of localities throughout the country. Further explication of EPA Region 9's expectation concerning these determinations is appropriate and is presented below.

The fundamental requirement of this task is to establish a strong tie between the proposed lower water quality level and "important" economic or social development. If the party seeking the change in water quality cannot demonstrate the relationship between such development and water quality, then the proposed action is prohibited.

Demonstration of important economic or social development entails two steps. First, the party should describe and analyze the current state of economic and social development in the area that would be affected. The purpose of this step is to determine the "baseline" economic and social status of the affected community, i.e., the measure against which the effect of the water quality downgrade is judged. The area's use or dependence upon the water resource affected by the proposed action should be described in the analysis. The following factors should normally be included in the baseline analysis:

- Population
- Area employment (numbers employed, earnings, major employers);
- Area income (earnings from employment and transfer payments, if known);

- Manufacturing profile: types, value, employment, trends;

- Government fiscal base: revenues by source (employment and sales taxes, etc.)

Second, the party seeking the change in water quality should then demonstrate the extent to which the sought-for level of water quality would create an incremental increase in the rate of economic or social development and why the change in water quality is necessary to achieve such development. The party should provide analysis, along with the supporting data used in its preparation, showing the extent to which the factors listed above will benefit from the change in water quality requested. The analysis should demonstrate why such economic and social development requires the lower water quality. Other alternatives or changes in the project or other mitigation measures which would prevent degradation of water quality should be identified in this analysis. The following factors may be included in the analysis of incremental effects expected to result from the degradation in water quality:

- Expected plant expansion;

- Employment growth;

- Direct and indirect income effects;

- Increases in the community tax base

Other components of this analysis could include an assessment of the overall environmental benefits to be achieved by the proposed action and the tradeoffs to be considered among the various media. The relative costs of various alternatives to the proposed action could also be analyzed.

The requirements for a given analysis will be site-specific, depending upon factors such as data availability, conditions specific to the relevant water body, the area of impact (city, county, State-wide), etc. The economic analysis may include estimation of the treatment costs necessary to maintain existing water quality; e.g. land treatment or advanced treatment. Staff of the EPA Regional office are available to assist States in determining the exact requirements of an analysis of

specific proposals to lower water quality. In addition, the Economic Analysis Branch in EPA Headquarters' Office of Water can assist State and Regional staff, when necessary.

Task D - Complete Intergovernmental Coordination and Public Participation

Public notification pursuant to 40 CFR 131.12 is required for all actions that lower water quality in Tier II waters. EPA requires that proposed actions which degrade water quality be reviewed by other appropriate agencies and that the public be given an opportunity to comment.

Documentation and public notification under antidegradation need not be a lengthy process in many cases and can be combined with other actions that require public notification. The public participation requirement may be met by holding a public hearing, e.g., as part of the adoption of an NPDES permit, as long as proper notice of a standards action is provided to the public (see WQS Handbook). Intergovernmental coordination consists of requests for review of proposed actions by affected local, State and Federal agencies, such as area-wide planning agencies, fish and wildlife agencies, etc.

The following is a summary of the public notification required to comply with the antidegradation provisions of the WQS regulation:

- A statement that the action must comply with the State's antidegradation policy and a description of the policy.

- A determination that existing uses will be maintained and protected. This will require an assessment and documentation for public review of (a) the amount the water quality currently exceeds that necessary to protect the existing and designated uses, and (b) the amount that water quality will be lowered as a result of the proposed action (see Task A).

- A summary of other actions, if any, that have lowered water quality and a determination of any cumulative impacts.

- A determination that lower water quality is necessary to

accommodate important economic or social development. This will require a detailed analysis or the rationale used to determine that a detailed analysis is not required (see Tasks A and C).

- A description of the intergovernmental coordination that has taken place.

- A determination that there has been achieved the highest statutory and regulatory requirements for all new and existing point sources and all cost-effective and reasonable best management practices for non-point sources.

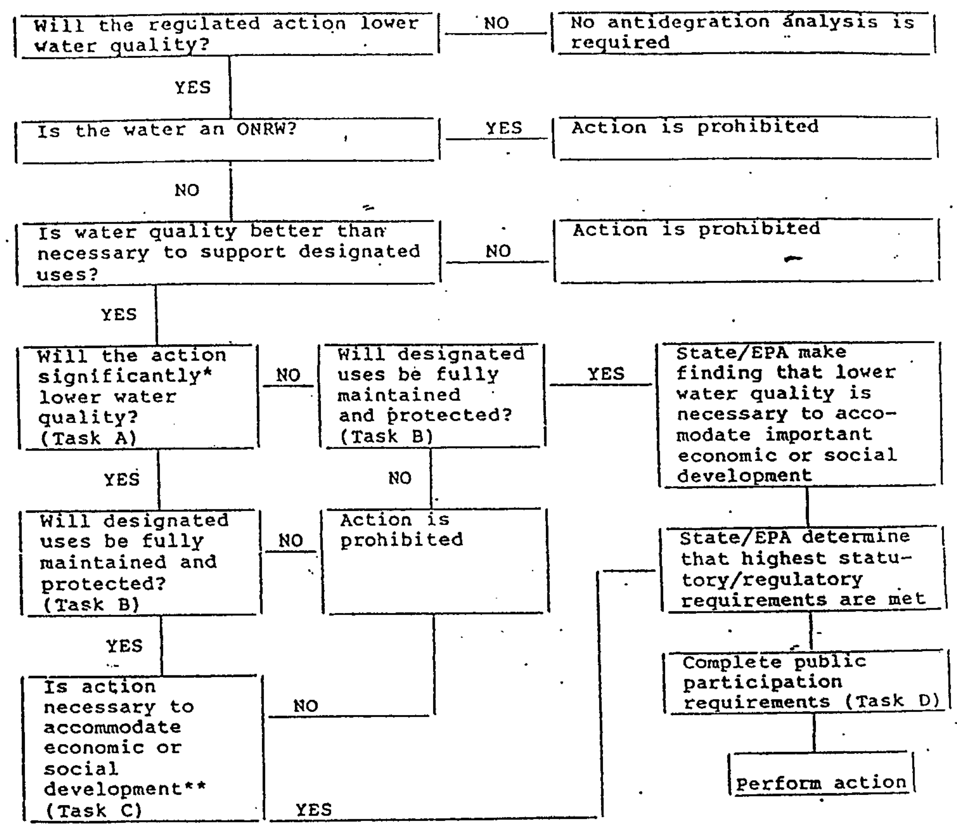
OTHER CONSIDERATIONS

1. The decision criteria for determining that detailed water quality and economic analyses are needed may vary with the types of chemical pollutants. Some chemicals are believed to elicit an effect at a certain concentration (i.e., threshold chemicals). Other chemicals (i.e., non-threshold chemicals) have no safe level. Non-threshold chemicals include carcinogens, mutagens and teratogens. States are urged to apply more stringent review procedures to non-threshold chemicals.

2. NPDES permits do not routinely contain numerical limits for all of the substances found in a discharger's effluent. Nevertheless, all substances are subject to antidegradation policy implementation, whether or not they are specifically limited in the permit. To apply antidegradation to substances not currently limited in the permit, the State can utilize the notification procedures specified in 40 CFR 122.42, requiring dischargers to notify the State pollution control agency of any actual or anticipated change in effluent characteristics, as compared with those existing at the time the permit was issued.

FIGURE 1

Antidegradation Flow Chart



*Significance level and effect of cumulative impacts as defined by State

**Based on criteria defined by State

Appendix II-g

DEIS Distribution List

Organization/Dept.	Addressee (last name)	Addressee (first name)	Title	Division	Address
Accounting & Gen. Services	Tamura	Ms. Jolyn G.	Archivist		Dept. of Accounting & Gen. Services Iolani Palace Grounds Honolulu, HI 96813
Agriculture	Nakatani	Mr. James J.	Director		Department of Agriculture State of Hawaii 1428 South King Street Honolulu, HI 96814
Army	Army Directorate of Public Works				U.S. Army Garrison Hawaii ATTN: Environmental Management Office Schoffield Barracks, HI 96857-5000
Army	Cababa	Col. Robin R.	Acting Commander, Division Engineer		U.S. Army Corps of Engineers Pacific Ocean Division Building 230 Fort Shafter, HI 96858
Army	Commander				U.S. Army Pacific ATTN: APEN Fort Shafter, HI 96858-5100
Army	Dadey	Kathy			U.S. Army Corps of Engineers Pacific Ocean Division Building 230 Fort Shafter, HI 96858
Army	Director of Engineering				Department of the Army U.S. Army Engineer District Honolulu Fort Shafter, HI 96858-5440
Board of Water Supply	Sato	Mr. Raymond	Manager/ General Engineer		Board of Water Supply City & County of Honolulu 630 South Beretania Street Honolulu, HI 96843
City Council	Hanneman	Councilman Mufi			City Council 530 South King Street, Rm 202 Honolulu, HI 96813

Organization/Dept.	Addressee (last name)	Addressee (first name)	Title	Division	Address
City Council	Mercado-Kim	Councilwoman Donna			City Council 530 South King Street, Rm 202 Honolulu, HI 96813
Coast Guard	Collins	Rear Adm Thomas H.	Commander		U.S. Coast Guard 14th Coast Guard District 300 Ala Moana Boulevard, Ste. 1953 Honolulu, HI 96850-4892
Commerce	Laurs	Dr. Michael	Director	National Marine Fisheries Service	2570 Dole Street Honolulu, HI 96822
Commerce	Naughton	Mr. John		NOAA Fisheries Pacific Area Office	2570 Dole Street Honolulu, HI 96822
Commerce	Simonds	Ms. Kitty	Executive Director	Western Pacific Regional Fishery Management Council	1164 Bishop Street, Suite 1405 Honolulu, HI 96813
Environmental Quality Control	Gill	Mr. Gary	Director		Office of Environmental Quality Control State of Hawaii 235 S. Beretania St.,Room 702 Honolulu, HI 96813
Hawaiian Affairs	Lee	Ms. Lynn	Officer	Land & Natural Resources	Office of Hawaiian Affairs 711 Kapiolani Boulevard, Suite 500 Honolulu, HI 96813
Health	Arizumi	Mr. Thomas	Chief	Environmental Management Division	Department of Health 919 Ala Moana Blvd., Room 300 Honolulu, HI 96814
Health	Lau	Mr. Denis	Chief	Clean Water Branch	Department of Health 919 Ala Moana Blvd., Room 309 Honolulu, HI 96814
Health	Miike, M.D., J.D.	Lawrence H.	Director		Department of Health State of Hawaii P.O. Box 3378 Honolulu, HI 96801

Organization/Dept.	Addressee (last name)	Addressee (first name)	Title	Division	Address
Health	Nagamine	Mr. Wilfred K.	Manager	Clean Air Branch	Department of Health 919 Ala Moana Blvd., Room 203 Honolulu, HI 96814
Health	Tulang	Mr. Dennis	Chief	Wastewater Branch	Department of Health 919 Ala Moana Blvd., Room 309 Honolulu, HI 96814
Health	Wong	Mr. William K.C.	Chief	Safe Drinking Water Branch	Department of Health 919 Ala Moana Blvd., Room 308 Honolulu, HI 96813
Hickam AFB	Blake	Lt. Mark			15 CES/CEVP 75 H Street Hickam AFB, HI 96853-5233
Hickam AFB	Brown	Col. Bruce			15 ABW/CC 800 Scott Circle Hickam AFB, HI 96853-5328
Hickam AFB			Chief of Planning		15 CES/CECP 75 H Street Hickam AFB, HI 96853-5233
Hickam AFB	Davis	Major Joe	Chief		15 ABW/PAI 800 Scott Circle Hickam AFB, HI 96853-5328
Hickam AFB	Director of Housing				15 CES/CEH 900 Hangar Avenue Hickam AFB, HI 96853-5233
Hickam AFB	Hooper	Lt. Col. John			10 Worchester Ave Hickam AFB, HI 96818
Hickam AFB	McGhee	Michael F.	Chief Environmental Flight		15 CES/CEB 75 H Street Hickam AFB, HI 96853-5233
Hickam AFB	Mielke	Sgt. Ryan	Editor	Newspaper	15 ABW/PAI 800 Scott Circle Hickam AFB, HI 96853-5328
Hickam AFB	Szatanek	Capt. Jeff			HQ PACAF/CEVP 25 E Street Suite D-306 Hickam AFB, HI 96853-5412
Hickam AFB	Vaughn	David S.			HQ PACAF/CEVP 25 E Street Suite D-306 Hickam AFB, HI 96853-5412
Hickam Harbor	Zak	Stephan	Harbor Master		15 SVS/SVRO 900 Hangar Ave. Hickam AFB, HI 96853-5426
Land and Natural Resources	Devick	Mr. William	Acting Administrator	Aquatic Resources Division	Dept. of Land & Natural Resources 1151 Punchbowl Street, Room 330 Honolulu, HI 96813
Land and Natural Resources	Hibbard, PHD	Don	Director	State Historic Preservation Division	Dept. of Land & Natural Resources 33 South King Street, 6th Floor Honolulu, HI 96813
Land and Natural Resources	Monden	Mr. Andrew	Chief Engineer	Water & Land Development Branch	Dept. of Land & Natural Resources P.O. Box 373 Honolulu, HI 96809
Land and Natural Resources	Uchida	Mr. Dean	Administrator	Land Division	Dept. of Land & Natural Resources 1151 Punchbowl Street, Room 220 Honolulu, HI 96813
Land and Natural Resources	Wilson	Mr. Michael D.	Chair		Department of Land & Natural Resources State of Hawaii P.O. Box 621 Honolulu, HI 96809
Land Utilization	Sullivan	Ms. Jan	Director		Department of Land Utilization City & County of Honolulu 650 South King Street, 7th Floor Honolulu, HI 96813

Organization/ Dept.	Addressee (last name)	Addressee (first name)	Title	Division	Address
Library	Goo	Ms. Beryl	Head Librarian	Ewa Beach Public School Library	91-950 North Road Ewa Beach, HI 96706
Library	Cofman	Ms. Floriana		Pearl City Public Library	1138 Waimano Home Road Pearl City, HI 96782
Library	Spencer	Mrs. Caroline	Director	Hawaii State Library	478 South King Street Honolulu, HI 96813
Mamala Bay Study Commision					Mamala Bay Study Commission 900 Fort Street Mall, Suite 1300 Honolulu, HI 96813
MK Engineers, Ltd.	Uyeda	Paul	P.E.		MK Engineers, Ltd. 286 Kalihi Street Honolulu, HI 96819
Navy	Christopherson	Greg	Harbormaster		U.S. Naval Station Box 8 Code 31 Pearl Harbor, HI 96860-6000
Navy	Shrewsbury	Capt. John			Naval Base Pearl Harbor Box 110, Code N4 Pearl Harbor, HI 96860-5020 ATTN: Clyde Yokota
Navy			Division Officer		Commanding Officer, Staff Civil U.S. Naval Station Box 10, Code 20 Pearl Harbor, HI 96860-6000 ATTN: Lt. J.G. Bain
Navy	Geddie	John			8040 Bellamah Ct. NE Albuquerque, NM 87110
Navy	Hirano	Wesley	Environmental Engineer		Code 20 Naval Station Pearl Harbor Pearl Harbor, HI 96860-6000

Organization/ Dept.	Addressee (last name)	Addressee (first name)	Title	Division	Address
Navy	Kam	Donald	Staff Civil Engineer		Code 21 Naval Station Pearl Harbor Pearl Harbor, HI 96860-6000
Navy	Roome	William H.	Environmental Public Affairs Officer		Commander, Naval Base Pearl Harbor Box 1160 Naval Base Pearl Harbor Pearl Harbor, HI 96860-5020
Navy	Harper	Lt. Commander David			Code 30, Box 8 Port Operations Naval Station Pearl Harbor Pearl Harbor, HI 96860-6000
Navy	Takeuchi	Jeff			Code 612 US Naval Submarine Base Pearl Harbor, HI 96860
Navy Public Works Center	Eisenpress	Nate	Staff Civil Engineer		U.S. Navy Public Works Center Code 22 Pearl Harbor, HI 96860
Navy Public Works Center	Emsley	Denise	Public Works Officer		U.S. Navy Public Works Center Honolulu, HI 96860
Navy Public Works Center	Higuchi	Joanne		Environmental Compliance	U.S. Navy Public Works Center Code 09E Pearl Harbor, HI 96860
Navy Public Works Center	Iha	Preston	Plant Engineer	Utilities Department	U.S. Navy Public Works Center Code 646 Pearl Harbor, HI 96860
Navy Public Works Center	Puana	Reggie	Division Director	Utilities Department	U.S. Navy Public Works Center Code 640 Pearl Harbor, HI 96860
Navy Public Works Center	Steel	Francis	Staff Civil Engineer		U.S. Navy Public Works Center Code 22 Pearl Harbor, HI 96860

Organization/ Dept.	Addressee (last name)	Addressee (first name)	Title	Division	Address
Neighborhood Board	Miura	Mr. Mike	Chairman	Alea Neighborhood Board	99-656 Aliipoe Drive Aiea, HI 96701
Neighborhood Board	Souza	Mr. Jerry	Chairman	Pearl City Neighborhood Board	P.O. Box 19 Pearl City, HI 96782
Neighborhood Board	Tanimoto	Mr. Grant		Aliamanu Neighborhood Board	3447 Ala Haukulu Street Honolulu, HI 96818
Office of the Mayor	Harris	Mayor Jeremy			Office of the Mayor City & County of Honolulu City Hall 530 South King Street, Rm 300 Honolulu, HI 96813
PACDIV	Ige	Ed	General Engineer, Project Manager		Code 5014A PACNAVFACENGCOM Building 258 Makalapa Dr. Pearl Harbor, HI 96860-7300
PACDIV	Kaku	Melvin			Code 23 Environmental Planning Division PACNAVFACENGCOM Pearl Harbor, HI 96860-7300
PACDIV	Kasaoka	Gary			Code 231GK Environmental Planning Division PACNAVFACENGCOM Pearl Harbor, HI 96860-7300
PACDIV	Koga	Mike			Code 048 PACNAVFACENGCOM Pearl Harbor, HI 96860-7300

Organization/ Dept.	Addressee (last name)	Addressee (first name)	Title	Division	Address
PACDIV	Matoi	Shirley			Code 405 PACNAVFACENGCOM Pearl Harbor, HI 96860-7300
PACDIV	Poentis	Aaron	Environmental Engineer		Code 1811 PACNAVFACENGCOM Pearl Harbor, HI 96860-7300
PACDIV	Sullivan, Esq.	Paul M.			Code 09C PACNAVFACENGCOM Building 258 Makalapa Dr. Pearl Harbor, HI 96860-7300
PACDIV	Sumida	Karen			Code 1811 PACNAVFACENGCOM Pearl Harbor HI 96860-7300
PACDIV	Wong	Orrin			Code 1811 PACNAVFACENGCOM Pearl Harbor, HI 96860-7300
Planning Department	Onishi	Mr. Pat	Chief Planning Officer		Planning Department City & County of Honolulu 650 South King Street, 8th Floor Honolulu, HI 96813
Public	Baba	Keith & Suzanne			1640 Hooheke Street Pearl City, HI 96782
Public	Clark	John			P.O. Box 25277 Honolulu, HI 96825
Public (SSFM sub)	Grace	Robert			1939 Kahela Drive Honolulu, HI 96822
Public	Jenson	Sidney			6940 Kehampton Farmington, Utah 84015
Public	Okawa	Dwight			1357 Halekoa Drive Honolulu, HI 96821

Organization/Dept.	Addressee (last name)	Addressee (first name)	Title	Division	Address
Public	Taguchi	Ben			P.O. Box 185 Honolulu, HI 96810
Public	Tasaka	Rossyn			1411 Ala Leleu St. Honolulu, HI 96818
Public	Terri	Marie			P.O. Box 4932 Kaneohe, HI 96744
Public Interest				Blue Ocean Preservation Society	P.O. Box 1850 Kihei, HI 96753
Public Interest				Conservation Council for Hawaii	P.O. Box 2923 Honolulu, HI 96802
Public Interest				Earthtrust	Aikahi Park Shopping Center 25 Kaneohe Bay Dr., Suite 205 Kailua, HI 96734
Public Interest				Greenpeace Foundation of Hawaii	P.O. Box 277 208 Kihei, HI 96753
Public Interest				Hawaii Chapter American Fisheries Society	861 Hokulani Street Honolulu, HI 96825
Public Interest				Hawaii Office Natural Resources Defense Council	212 Merchant Street, Suite 203 Honolulu, HI 96813
Public Interest	Wong	Ms. Donna	Executive Director	Hawaii's Thousand Friends	305 Hahani Street, Suite 282 Kailua, HI 96734
Public Interest	Curtis	Mr. Henry	Executive Director	Life of the Land	1111 Bishop Street, Suite 503 Honolulu, HI 96813
Public Interest	Kamau'u	Ms. Mahealani	Executive Director	Native Hawaiian Legal Corporation	1164 Bishop Street, Suite 1205 Honolulu, HI 96813
Public Interest	Achitoff, Esq.	Paul		Sierra Club Legal Defense Fund, Inc.	223 South King Street, 4th Floor Honolulu, HI 96813
Public Interest				Sierra Club Hawaii Chapter	P.O. Box 2577 Honolulu, HI 96803
Public Interest				The Ocean Recreation Council of Hawaii	P.O. Box 661 Kailua, HI 96734
Public Interest	Cayan	Ms. Phyllis	Chairperson	Oahu Burial Committee	98-295 Ualo Street, Room X4 Aiea, HI 96701
Public Interest	Kubota	Stephen T.		Ahupua'a Action Alliance	44-281 Mikiola Dr. Kaneohe, HI 96744
Public Interest	Madlener	Fred		Hawaii's Thousand Friends	46-196 Yacht Club St. Kaneohe, HI 96744
Public Interest	Nihipali	Mr. Kunani		Hui Malama I Na Kupuna O Hawaii Nei	P.O. Box 190 Haleiwa, HI 96712-0190
Public Interest	Norris	Mr. Jerry	Executive Director	Pacific Basin Development Council	711 Kapiolani Blvd., Suite 1075 Honolulu, HI 96813
Public Interest	Olds	Ms. Clara		Save Our Bays & Beaches	15 Hamakua Drive, Suite 727 Kailua, Hawaii 96734
Public Interest	Reid	Mr. Shawn		Surfrider Foundation	66-590 Kamehameha Hwy., Suite 727 Haleiwa, HI 96712
Public Interest	Reppun	Mr. John		Hui Malama Aina O Koolau	47-200 Waihee Road Kaneohe, HI 96744
Public Interest	Yardley	Toni		Women of Hale O' Papa	44-114 Keaalau Pl. Kaneohe, HI 96744
Public Works	Shimada	Jonathan K.	Director		Department of Public Works City & County of Honolulu 650 South King Street, 11th Floor Honolulu, HI 96813

Organization/ Dept.	Addressee (last name)	Addressee (first name)	Title	Division	Address	Phone number	Comments received?	Receive DEIS/FEIS?
Public Works	Sprague	Dr. Kenneth	Director		Department of Public Works City & County of Honolulu 650 South King Street, 11th Floor Honolulu, HI 96813	523-4341		
ROICC MIDPAC	Pang	Hiram			ROICC MIDPAC Box 104 Pearl Harbor, HI 96860	471-2221		
Sea Engineering	Rocheleau	Bob			Sea Engineering Makai Research Pier Waimanalo, HI 96795	259-7966 259-8143 (fax)		
State Capitol	Cachola	Representative Romy M.		House	State Capitol 415 S. Beretania Street Honolulu, HI 96813	586-6110		
State Capitol	Graulty	Senator Rey		Senate	State Capitol 415 S. Beretania Street Honolulu, HI 96813	586-6670		
State Capitol	Ige	Senator David Y.		Senate	State Capitol 415 S. Beretania Street Honolulu, HI 96813	586-6230		
State Capitol	Iwase	Senator Randall Y.		Senate	State Capitol 415 S. Beretania Street Honolulu, HI 96813	586-670		
State Capitol	Mizuguchi	Senator Norman		Senate	State Capitol 415 S. Beretania Street Honolulu, HI 96813	586-6870		
State Capitol	Pepper	Representative Lennard J.		House	State Capitol 415 S. Beretania Street Honolulu, HI 96813	586-6320	Yes; @ scoping metg	Yes
State Capitol	Takumi	Representative Roy M.		House	State Capitol 415 S. Beretania Street Honolulu, HI 96813	586-6170		
State Planning	Pai	Mr. Gregory	Director		Office of State Planning State of Hawaii 415 S. Beretania Street, Room 409 Honolulu, HI 96813	587-2846		
Transportation	Fujikawa	Mr. Thomas	Chief	Harbors Division	Department of Transportation 79 S. Nimitz Highway Honolulu, HI 96813	587-1930		
U.S. Department of Agriculture	Kaneshiro	Mr. Kenneth M.	State Conservationist	Natural Resources Conservation Service	U.S. Department of Agriculture P.O. Box 50004 Honolulu, HI 96850-0001	541-2600		
U.S. Dept. of the Interior	Meyer	Mr. William	District Chief	Geological Survey Water Resources Div.	U.S. Dept. of the Interior 677 Ala Moana Blvd., Suite 415 Honolulu, HI 96813	522-8290		
U.S. Dept. of the Interior	Smith	Mr. Robert	Ecoregion Manager	Fish & Wildlife Service	U.S. Dept. of the Interior P.O. Box 50156 Honolulu, HI 96850	541-2749		
U.S. EPA	Marcus	Ms. Felicia	Regional Administrator	U.S. Environmental Protection Agency, Region IX	75 Hawthorne Street San Francisco, CA 94105			
U.S. EPA	Tsuhako	Ms. Vicki H.	Manager	Pacific Islands Contact Office	U.S. Environmental Protection Agency 300 Ala Moana Blvd., Room 5124 Honolulu, HI 96813	541-2710 541-2712 (fax)		
Univeristy of Hawaii	Harrison PHD	John T.	Director	Environmental Center	University of Hawaii 2250 Campus Road, Crawford 317 Honolulu, HI 96822	956-7361		
Univeristy of Hawaii	Helsley	Dr. Charles E.	Director	Sea Grant College Program	University of Hawaii 1000 Pope Road, MSB, Room 220 Honolulu, HI 96822	956-7031		

Organization/ Dept.	Addressee (last name)	Addressee (first name)	Title	Division	Address	Phone number	Comments received?	Receive DEIS/FEIS?
University of Hawaii	Fujioka PHD	Roger S.	Director	Water Resources Reseach Center	University of Hawaii 2540 Dole Street, Holmes Hall 283 Honolulu, HI 96822	956-7847		
University of Hawaii	Maynard	Dr. Sherwood	Director	Marine Option Program	University of Hawaii 1000 Pope Road, Room 229 Honolulu, HI 96822	956-8433		
Wastewater Management	Limtiaco	Mr. Felix B.	Director		Department of Wastewater Management City & County of Honolulu 650 South King Street, 3rd Floor Honolulu, HI 96813	527-6663		

Appendix II-h

Notice of Availability Announcement

Honolulu-Star Bulletin

ANNOUNCEMENT OF PUBLIC HEARING AND NOTICE OF AVAILABILITY OF THE DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE PROPOSED CONSTRUCTION OF A REPLACEMENT OUTFALL FOR THE WASTEWATER TREATMENT PLANT AT FORT KAMEHAMEHA, PEARL HARBOR, OAHU, HAWAII

The Department of the Navy announces the availability of the Draft Environmental Impact Statement (DEIS) for the Proposed Construction of a Replacement Outfall for the Wastewater Treatment Plant (WWTP) at Fort Kamehameha. The replacement outfall will discharge offshore of the treatment plant into the open coastal water of Mamala Bay and will consist of a 42-inch diameter, 2.4-mile long pipeline, including a 656-foot diffuser segment at a depth of 150 feet. The existing outfall for the WWTP at Fort Kamehameha discharges into the Pearl Harbor Estuary, which is classified as a Water Quality Limited Segment (WQLS) by the State of Hawaii. The proposed outfall will eliminate the need to discharge treated wastewater into the WQLS. Alternatives to the proposed action, such as upland disposal of treated effluent by subsurface injection, reclamation of effluent for reuse, and "no action" are identified and evaluated in the DEIS.

Pursuant to Section 102(2)(c) of the National Environmental Policy Act (NEPA) of 1969, as implemented by the Council on Environmental Quality regulations (40 CFR Parts 1500-1508), the Navy has prepared and filed with the U.S. Environmental Protection Agency the above referenced DEIS.

A public hearing to receive comments on the DEIS will be held on December 17, 1997, at 7:00 p.m. at the Radford High School cafeteria, 4361 Salt Lake Boulevard, Honolulu. The public hearing will be conducted by the Navy.

Government agencies, elected officials, individuals, and community organizations are invited to attend or be represented at the hearing. Oral statements will be heard and transcribed by a stenographer. To assure accuracy of the record, written statements in addition to, or in lieu of, oral comments will be accepted. Both oral and written statements will become part of the public record on this study, with equal weight given to each. In the interest of available time, speakers will be asked to limit their comments to five minutes. Longer statements should be verbally summarized at the public hearing, and the complete text either submitted at the hearing desk or mailed to the point of contact identified below.

All mailed statements must be postmarked by January 9, 1998 to be incorporated in the official record.

The DEIS has been placed for viewing at libraries as follows: Hawaii State Main Library, Salt Lake Moanalua Public Library, Aiea Public Library, Pearl City Public Library, and Ewa Beach Public School Library.

For more information, requests for single copies of the DEIS, and submittal of written comments, the point of contact is Mr. Gary Kasaoka; telephone (808) 471-9338; fax (808) 474-5909; Internet [gkasaoka@efdpac.navfac.navy.mil]. Mail should be addressed to: Commander, Pacific Division, Naval Facilities Engineering Command, Attn: Environmental Planning Division (Code 231GK), Pearl Harbor, HI 96860-7300.

(Hon. S.-B.: Nov. 27, 28, 29, 1997) (SB-8810)

Honolulu Advertiser

ANNOUNCEMENT OF PUBLIC HEARING AND NOTICE OF AVAILABILITY OF THE DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE PROPOSED CONSTRUCTION OF A REPLACEMENT OUTFALL FOR THE WASTEWATER TREATMENT PLANT AT FORT KAMEHAMEHA, PEARL HARBOR, OAHU, HAWAII

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For more information, requests for single copies of the DEIS, and submittal of written comments, the point of contact is Mr. Gary Kasaoka; telephone (808) 471-9338; fax (808) 474-5909; Internet [gkasaoka@efdpac.navfac.navy.mil]. Mail should be addressed to: Commander, Pacific Division, Naval Facilities Engineering Command, Attn: Environmental Planning Division (Code 231GK), Pearl Harbor, HI 96860-7300.

(Hon. Adv.: Nov. 30, 1997) (A-46776)

mental Planning Division (Code 231GK), Pearl Harbor, HI 96860-7300.

(Hon. Adv.: Nov. 28, 29, 1997) (A-46775)

Appendix II-i

DEIS Public Hearing Attendance Records

ATTENDANCE RECORD - PLEASE PRINT LEGIBLY

Public Hearing - DEIS for Outfall Replacement at the Wastewater Treatment Plant at
Fort Kamehameha, Navy Public Works Center, Pearl Harbor, Oahu, Hawaii

December 17, 1997, 7:00 p.m., Radford High School Library

NAME	COMPLETE MAILING ADDRESS (INCLUDING ZIP CODE)	REPRESENTING	DO YOU PLAN TO SPEAK? YES	DO YOU PLAN TO SPEAK? NO	DO YOU WISH TO RECEIVE A COPY OF THE FEIS? YES	DO YOU WISH TO RECEIVE A COPY OF THE FEIS? NO
Bob GRACE	UH, Dept. of Civil Eng'g Holmes 383, Hon., HI 96822	UH		✓	✓	
Walter CARVALHO	4300 RADFORD DR., NAVY PUBLIC WORKS CENTER Code 09SCE	STAFF CIVIL OFFICE PWC 09SCE		✓	✓	
BRIAN MADA	45-416 OHAHA ST KANEOHE, HI 96744	SSFM ENGR		✓	✓	
Stephen T Kubota	44-281 Mikiola Dr. Kaneohe, HI 96744	Ahupuaa Action Alliance	✓		✓	
BEN TAGUCHI	2924 ALA OLOA PL HNL 96818 - self					
Edward Iida	94-342 Keahiki Pl., Mililani 96789	Self		✓		✓
NATE EISENPRESS	NAVY PWC C/09SC	PWC		✓	✓	
Charles K Torigoe	2816 Varsity Circle #1 Hon 96826			✓	✓	
HAROLD K. NAGATO	851 NANA HONUA ST	BEST		✓	✓	
Joanne Higuchi	94-344 Hakamoa st. Mililani Hon 96825	—		✓		✓
James Kwong	1144 10th Ave, Hon. HI 96816	Woodward-Clyde Federal Services		✓		✓
Bob Rocheleau	Makai Pier, Waimanalo 96795	Sea Eng Inc		✓	✓	

ATTENDANCE RECORD - PLEASE PRINT LEGIBLY

Public Hearing - DEIS for Outfall Replacement at the Wastewater Treatment Plant at Fort Kamehameha, Navy Public Works Center, Pearl Harbor, Oahu, Hawaii

December 17, 1997, 7:00 p.m., Radford High School Library

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Bob GRACE	UH, Dept. of Civil Eng'g Holmes 383, Hnl., HI 96822	UH		✓	✓	
Walter Carvalho	4300 RADFORD DR., NAVY PUBLIC WORKS CENTER Code 09SCE	STAFF CIVIL OFFICE PWC Code 09SCE		✓	✓	
Brinkl Mata	45-416 Ohaha St Kaneohe, HI 96744	SSFM ENGR		✓	✓	
Stephen T Kubota	44-281 Mikiola Dr. Kaneohe, Hi 96744	Ahupua'a Action Alliance	✓		✓	
BEN TAGUCHI	2924 ALA OLOA PL HNL 96818 - self					
Edward Iida	94-342 Kealiilile Pl., Mililani 96789	Self		✓		✓
NATE EISENPRESS	NAVY PWC C/09SC	PWC		✓	✓	
Charles K Torigoe	2816 Varsity Circle #1 Hon 96826			✓	✓	
HAROLD K. NAGATO	851 NANA HONUA ST	BEST		✓	✓	
Joanne Higuchi	94-344 Hakamoa St. Mililani Hon 96825	—		✓		✓
James Kwong	1144 10th Ave, Hon. HI 96816	Woodward-Clyde Federal Services		✓		✓
Bob Rocheleau	Makai Pier, Waimanalo 96795	Sea Eng. Inc		✓	✓	

Appendix II-j

DEIS Comments and Responses

United States Department of the Interior

U.S. GEOLOGICAL SURVEY

WATER RESOURCES DIVISION
677 Ala Moana Boulevard, Suite 415
Honolulu, Hawaii 96813

November 25, 1997

Mr. Gary Kasaoka
Pacific Division
Naval Facilities Engineering Command
Pearl Harbor, Hawaii 96860-7300

Dear Mr. Kasaoka:

Subject: Draft Environmental Impact Statement (DEIS)
Outfall Replacement for Wastewater Treatment Plant
at Fort Kamehameha, Navy Public Works Center
Pearl Harbor, Hawaii

The staff of the U.S. Geological Survey, Water Resources Division, Hawaii District, has reviewed the DEIS, and we have no comments to offer at this time.

Thank you for allowing us to review the report. We are returning it for your future use.

Sincerely,

William Meyer

William Meyer
District Chief

Enc.

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
(MAKALAPA, HI)
PEARL HARBOR, HAWAII 96860-7300

5090P.1F3C
Ser 231/ 2181

8 JUN 1998

Mr. William Meyer
U.S.G.S. Water Resources Division
U.S. Department of the Interior
677 Ala Moana Boulevard, Suite 415
Honolulu, HI 96813

Dear Mr. Meyer:

Subj: DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS) FOR OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR, HAWAII

Thank you for your letter of November 25, 1997, in which you indicated that your agency had reviewed the DEIS for the proposed action and had no comments to offer at this time.

Should you have any questions, please contact Mr. Gary Kasaoka (Code 231GK) at 471-9338 or by facsimile transmission at 474-5909.

Sincerely,

Melvin N. Kaku

MELVIN N. KAKU
Director
Environmental Planning Division

Copy to:
Belt Collins Hawaii
680 Ala Moana Boulevard, First Floor
Honolulu, HI 96813

DEPARTMENT OF PUBLIC WORKS

CITY AND COUNTY OF HONOLULU

650 SOUTH KING STREET, 11TH FLOOR • HONOLULU, HAWAII 96813
PHONE: (808) 523-4341 • FAX: (808) 527-5857

JEREMY HARRIS
MAYOR

JONATHAN K. SHIMADA, PHD
DIRECTOR AND CHIEF ENGINEER
ROLAND D. LIBBY, JR
DEPUTY DIRECTOR

ENV 97-259

November 25, 1997

Mr. Gary Kasaoka (Code 231GK)
Pacific Division
Naval Facilities Engineering Command
Pearl Harbor, HI 96860-7300

Dear Mr. Kasaoka:

Subject: Draft Environmental Impact Statement (DEIS) Outfall Replacement for Wastewater Treatment Plant at Fort Kamehameha
TMK: 9-9-01: Por 13

We have reviewed the subject DEA and have no comments to offer at this time.

Should You have any questions, please contact Mr. Alex Ho, Environmental Engineer, at 523-4150.

Very truly yours,

JONATHAN K. SHIMADA, PhD
Director and Chief Engineer

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
(MAKALAPA, HI)
PEARL HARBOR, HAWAII 96860-7300

5090P.1F3C
Ser 231/ 1580
23 APR 1998

Dr. Jonathan K. Shimada, Ph.D.
Department of Public Works
City and County of Honolulu
650 South King Street, 11th Floor
Honolulu, HI 96813

Dear Dr. Shimada:

Subj: DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS) FOR OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR, HAWAII

Thank you for your letter of November 25, 1997, regarding the DEIS for the above referenced action. We understand that you have no comments to offer regarding the proposed action at this time.

Due to discovery of a soft-soil condition along the original outfall alignment proposed in the DEIS, a new alignment around the soft-soil area is being designed. A supplemental draft environmental impact statement (SDEIS) will be issued in the fall of this year to cover the new outfall alignment. All recipients of the original DEIS will remain on the distribution list to receive the SDEIS and other subsequent documents related to the EIS.

Should you have any questions, please contact Mr. Gary Kasaoka (Code 231GK) at 471-9338 or by facsimile transmission at 474-5909.

Sincerely,

MELVIN N. KAKU
Director
Environmental Planning Division

Copy to:
Belt Collins Hawaii
680 Ala Moana Boulevard, 1st Floor
Honolulu, HI 96813

BENJAMIN J. CAYETANO
GOVERNOR

STATE OF HAWAII
DEPARTMENT OF TRANSPORTATION
HARBORS DIVISION
79 SO. NIMITZ HWY • HONOLULU, HAWAII 96813-4898

KAZU HAYASHIDA
DIRECTOR

DEPUTY DIRECTORS
[redacted]
GLENN M. OKIMOTO
BRIAN K. MINAAI

IN REPLY REFER TO:

HAR-EP
1486.98

December 1, 1997

Mr. Gary Kasaoka (Code 231GK)
Pacific Division
Naval Facilities Engineering Command
Pearl Harbor, Hawaii 96860-7300

Dear Mr. Kasaoka:

Subject: Draft Environmental Impact Statement (DEIS) for Proposed Outfall Replacement for Wastewater Treatment Plant at Fort Kamehameha Navy Public Works Center

Thank you for having provided the subject DEIS for our review and comment.

The proposed outfall replacement project has no apparent impacts on the State's commercial harbor operations. We have neither comments nor objections to offer.

Very truly yours,

for Harry H. Murakami
Thomas T. Fujikawa
Harbors Administrator

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
(MAKALAPA, HI)
PEARL HARBOR, HAWAII 96860-7300

5090P.1F3C
Ser 231/ 1795
7 MAY 1998

Mr. Thomas T. Fujikawa
Harbors Division Administrator
Hawaii Department of Transportation
79 South Nimitz Highway
Honolulu, HI 96813-4898

Dear Mr. Fujikawa:

Subj: DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS) FOR OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR, HAWAII

Thank you for your letter of December 1, 1997, regarding the DEIS for the above referenced action. We agree with your assessment that the project has no apparent impacts on the State's commercial harbor operations. We also understand that you have no additional comments or objections to the proposed action at this time.

Due to discovery of a soft-soil condition along the original outfall alignment proposed in the DEIS, a new alignment around the soft spot is being designed. A supplemental draft environmental impact statement (SDEIS) will be issued in the fall of this year to cover the new engineering challenge. All recipients of the original DEIS will remain on the distribution list to receive the SDEIS and other subsequent documents related to the EIS.

Should you have any questions, please contact Mr. Gary Kasaoka (Code 231GK) at 471-9338 or by facsimile transmission at 474-5909.

Sincerely,

Melvin N. Kaku
MELVIN N. KAKU
Director
Environmental Planning Division

Copy to:
Belt Collins Hawaii
680 Ala Moana Boulevard, 1st Floor
Honolulu, HI 96813

CITY COUNCIL

CITY AND COUNTY OF HONOLULU

HONOLULU, HAWAII 96813-3065 / TELEPHONE 547-7000

STEVE HOLMES
Councilmember

Phone: (808) 547-7002
Fax: (808) 527-5737
E-mail: holmes@co.honolulu.hi.us

December 2, 1997

Mr. Gary Kasaoka
(Code 231GK)
Pacific Division
Naval Facilities Engineering Command
Pearl Harbor, HI 96860-7300

Dear Mr. Kasaoka:

SUBJECT: FORT KAMEHAMEHA WWTP DEIS

The high level of treatment at Fort Kam makes reuse very attractive and requires a more thorough review of infiltration/inflow in order to reduce the high chloride counts caused by saltwater entry into the collection system. Triage of the collection system and the use of lining systems like Insituform could make the water usable. It would reduce flows, lower operating costs, and reduce odor and maintenance problems associated with hydrogen sulfide formation. The final EIS should more properly address this option given the multiple benefits.

Effluent reuse should be given a higher priority since it has been estimated that only 10 to 15 years of sustainable yield are available on Oahu. Reuse should be economically compared to new water development since it can replace potable water being used for agriculture. The DEIS doesn't do a decent market analysis for reuse. It could well be argued that in a 30-year analysis that the costs should be the avoided costs of desalinization without the negative impact of brine disposal.

The DEIS fails to properly assess the costs related to storm-related impacts to the outfall over the 30-year analysis. The City and County of Honolulu has had to do major outfall repair work. Continued use of the outfall also has ocean monitoring costs that are not properly factored.

The continued discharge into the ocean has a direct impact on the City's 301h waiver renewals. While stopping discharges into the Pearl Harbor WQLS will have a benefit, discharging into Mamala Bay close to the Sand Island outfall could have a significant impact. The FEIS needs to address this issue since the Mamala Bay Study already recommended that the Sand Island WWTP be upgraded at no small public expense and waiver renewals are not assured.

Thank you for the opportunity to respond to the DEIS. Please add me to your mailing list.

Sincerely,

Steve Holmes

Steve Holmes, Chair
Environment and Public Works Committee
Honolulu City Council

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
(MAKALAPA, HI)
PEARL HARBOR, HAWAII 96860-7300

5090P.1F3C
Ser 231/ 2348
22 JUN 1998

Mr. Steve Holmes, Chair
Environment and Public Works Committee
Honolulu City Council
530 South King Street, Second Floor
Honolulu, HI 96813-3065

Dear Mr. Holmes:

Subj: DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS) FOR OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT (WWTP) AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR

Thank you for your letter of December 2, 1997, in which you commented on the DEIS for the above proposed action. Our responses to your comments are as follows:

Comment: The high level of treatment at Fort Kamehameha makes reuse very attractive and requires a more thorough review of infiltration/inflow in order to reduce the high chloride counts caused by saltwater entry into the collection system. Triage of the collection system and the use of lining systems like Insituform could make the water usable. It would reduce flows, lower operating costs, and reduce odor and maintenance problems associated with hydrogen sulfide formation. The final EIS should more properly address this option given the multiple benefits.

Response: While the Navy's collection system is continuously undergoing upgrading and rehabilitation, the nature of the wastewater entering the WWTP at Fort Kamehameha includes significant amounts of saltwater. The Navy collection system is below the ground water table in a substantial portion of the base, and various parts of the collection extend under the harbor whereby saltwater infiltration into the sewerage is a major, ongoing problem. As you may be well aware, many of the City's infiltration and inflow problems on the windward side of Oahu are attributable to saltwater infiltration from the laterals to the main lines. These sewerage problems cannot be corrected by the application of Insituform. Bilge water from ships at Pearl Harbor is an additional source of saltwater, which is pumped to the WWTP at Fort Kamehameha. Finally, the ubiquitousness of saltwater in our system make triage of the entire collection system very difficult, if not impossible, and performing the necessary upgrades in the hope of obtaining irrigation quality effluent is not a feasible alternative at this time.

Revision of the DEIS: None.

Comment: Effluent reuse should be given a higher priority since it has been estimated that only 10 to 15 years of sustainable yield are available on Oahu. Reuse should be economically compared to new water development since it can replace potable water being used for agriculture. The DEIS doesn't do a decent market analysis for reuse. It could well be argued that in a 30 year analysis that the costs should be the avoided costs of desalination without the negative impact of brine disposal.

Response: The Navy generally supports the principle of reusing wastewater effluent. In the case of Fort Kamehameha, however, reuse of the treated effluent would be difficult to accomplish for the following reasons. First, the high salinity of the influent makes it

difficult to treat the effluent to a quality suitable for reuse. It is very expensive to remove the chloride ions to levels that would not poison the soils after a period of time. Second, while there are a few golf courses in the area capable of using nonpotable water, the paucity of large, open, landscaped areas suitable for a large scale irrigation program for economy of size severely limits the local demand and capacity for utilizing reuse water, at this time. Conveying treated effluent to arid areas elsewhere on Oahu would be cost prohibitive.

As indicated in Section 2.5.1.1, the "best case" scenario for sale of reclaimed effluent was incorporated into the reuse alternative. Distribution of effluent to more distant reuse sites would increase both capital and operating costs. Reuse of effluent from the City's Honouliuli WWTP, which does not require desalination, would be a much more attractive endeavor, especially since the plant is closer to potential users of nonpotable water. The Board of Water Supply's price structure needs to incorporate allocated costs of future source development. Future costs are speculative.

Revision of the DEIS: None.

Comment: The DEIS fails to properly assess the costs related to storm-related impacts to the outfall over the 30 year analysis. The City and County of Honolulu has had to do major outfall repair work.

Response: The problems encountered with existing outfalls in Hawaii, including their performance during recent hurricanes, are being accounted for in the design of the proposed outfall. It is not possible to predict extraordinary natural events with any certainty. Therefore, estimating costs incurred by such events would be speculative. On the other hand, we can expect "normal" maintenance and repair costs, similar to those associated with existing outfalls. These routine maintenance and repair costs include costs for biennial inspections of the outfall and diffuser repair, as needed. Because repair needs are difficult to project, costs are based on complete replacement of the diffuser piping mid-way through the life cycle of the outfall (year 15).

Revision of the DEIS: Section 2.3.6.2 has been revised to include information about routine maintenance and repair costs. Tables 2.3-3 and 2.3-4 have been revised to include costs for outfall inspection and diffuser replacement.

Comment: Continued use of the outfall also has ocean monitoring costs that are not properly factored.

Response: The monitoring program of the outfall is based on the requirements of the National Pollutant Discharge Elimination System permit. Considering the historical permitting actions of the Department of Health, we would anticipate that the monitoring effort would be essentially identical regardless if the outfall were to be located within the Pearl Harbor Entrance Channel or in Class A Open Coastal waters of Mamala Bay. The Navy believes that the Hawaii Administrative Rules clearly indicates that by placing the outfall in deeper ocean waters, the monitoring requirements may even be reduced as the anticipated diffuser location would better suited to assimilate the waste in the effluent.

Sampling and analysis costs are included in Table 2.2-1 for the no-action alternative and in Table 2.3-3 for the proposed outfall. These costs are based upon information from operations personnel.

Revision of the DEIS: None.

Comment: The continued discharge into the ocean has a direct impact on the City's 301h waiver renewals. While stopping discharges into the Pearl Harbor Water Quality Limited Segment will have a benefit, discharging into Mamala Bay close to the Sand Island outfall could have a significant impact. The FEIS needs to address this issue since the Mamala Bay Study already recommended that the Sand Island WWTP be upgraded at no small public expense and waiver renewals are not assured.

Response: Cumulative impact of the proposed outfall upon water quality in Mamala Bay is discussed in Section 4.4.1.6 and analyzed in detail in Appendix VII, *Time-Integrated Plume Modeling for the WWTP at For Kamehameha.* The discharge will have no significant impact upon water quality beyond the zone of mixing and will not exceed water quality standards by overlapping with the effluent plume from the Sand Island WWTP. Finally, the Navy disagrees with your claim that the Mamala Bay Study recommended that the Sand Island WWTP needs to be upgraded. The Navy's evaluation of the Mamala Bay Commission Report does not clearly indicate that the City's wastewater treatment plant needs to be upgraded.

Revision of the DEIS: None.

Should you have any questions, please contact Mr. Gary Kasaoka (Code 231GK) at 471-9338 or by facsimile transmission at 474-5909.

Sincerely,

Melvin N. Kaku

MELVIN N. KAKU
Director
Environmental Planning Division

Copy to:
Belt Collins Hawaii
680 Ala Moana Boulevard, First Floor
Honolulu, HI 96813

PLANNING DEPARTMENT
CITY AND COUNTY OF HONOLULU
650 SOUTH KING STREET, 8TH FLOOR • HONOLULU, HAWAII 96813-3017
PHONE: (808) 523-4711 • FAX: (808) 523-4950

JEREMY HARRIS
MAYOR

PATRICK T. ONISHI
CHIEF PLANNING OFFICER

DONA L. HANAIKE
DEPUTY CHIEF PLANNING OFFICER

RR 11/97-2266

December 2, 1997

Mr. Gary Kasaoka
Pacific Division
Naval Facilities Engineering Command
Pearl Harbor, Hawaii 96860-7300

Dear Mr. Kasaoka:

Draft Environmental Impact Statement (DEIS)
Outfall Replacement for Wastewater Treatment Plant
at Fort Kamehameha, Navy Public Works Center,
Pearl Harbor, Hawaii

We have reviewed the above DEIS in response to your department's request to realign and replace the wastewater treatment plant outfall at Fort Kamehameha, Pearl Harbor.

The project does not raise any specific General Plan Objective or Policy concerns; nor does the project directly affect the Development Plan for the Primary Urban Center and its special provisions for the area.

Should you have any questions, please contact Rob Reed of our staff at 523-4402.

Yours very truly,

PATRICK T. ONISHI
Chief Planning Officer

PTO:lh

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
(MAKALAPA, HI)
PEARL HARBOR, HAWAII 96860-7300

5090P.1F3C
Ser 231/1578
23 APR 1998

Mr. Patrick T. Onishi
Planning Department
City and County of Honolulu
650 South King Street, 8th Floor
Honolulu, HI 96813-3017

Dear Mr. Onishi:

Subj: DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS) FOR OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR, HAWAII

Thank you for your letter of December 2, 1997, regarding the DEIS for the above referenced action. We acknowledge your assessment that the project does not raise any specific General Plan Objective or Policy concerns, nor does it directly affect the Development Plan for the Primary Urban Center and its special provisions for the area.

Due to discovery of a soft-soil condition along the original outfall alignment proposed in the DEIS, a new alignment around the soft-soil area is being designed. A supplemental draft environmental impact statement (SDEIS) will be issued in the fall of this year to cover the new outfall alignment. All recipients of the original DEIS will remain on the distribution list to receive the SDEIS and other subsequent documents related to the EIS.

Should you have any questions, please contact Mr. Gary Kasaoka (Code 231GK) at 471-9338 or by facsimile transmission at 474-5909.

Sincerely,

MELVIN N. KAKU
Director
Environmental Planning Division

Copy to:
Belt Collins Hawaii
680 Ala Moana Boulevard, 1st Floor
Honolulu, HI 96813

DEPARTMENT OF WASTEWATER MANAGEMENT
CITY AND COUNTY OF HONOLULU
650 SOUTH KING STREET, 3RD FLOOR • HONOLULU, HAWAII 96813
PHONE: (808) 527-6663 • FAX: (808) 527-6675

JEREMY HARRIS
MAYOR

KENNETH E. SPRAGUE, P.E., Ph.D.
DIRECTOR
CHERYL K. OKUMA-SEPE, ESQ.
DEPUTY DIRECTOR

In reply refer to:
WCC 97-271

December 4, 1997

Mr. Stanley Y. Uehara, Director
Environmental Planning Division
Department of the Navy
Pacific Division Naval Facilities Engineering Command
Pearl Harbor, Hawaii 96860-7300

Dear Mr. Uehara:

Subject: **Draft Environmental Impact Statement (DEIS) for Proposed Outfall Replacement for Wastewater Treatment Plant at Fort Kamehameha Navy Public Works Center, Pearl Harbor, Hawaii**
TMK: 9-9-1:13

Please verify the data listing on Table 4.4-5, "Nutrient Levels (in $\mu g/l$) and Flow Rate of Wastewater Effluent from Three Treatment Plants" on page 4-28 of the subject document. The flow rate at Sand Island Wastewater Treatment Plant and Honouliuli Wastewater Treatment Plant are 78 million gallons per day and 26-27 million gallons per day, respectively.

If you have any questions, please contact Ms. Tessa Ching of the Service Control Branch at 523-4956 or Mr. Jared Lum of the Water Quality Division at 523-4654.

Sincerely,

Cheryl K. Okuma-Sepe
KENNETH E. SPRAGUE
Director

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
(MAKALAPA, HI)
PEARL HARBOR, HAWAII 96860-7300

5090P_1F3C
Ser 231/ 1681
01 MAY 1998

Mr. Kenneth Sprague, Director
Department of Wastewater Management
City and County of Honolulu
650 South King Street, 3rd Floor
Honolulu, HI 96813

Dear Mr. Sprague:

Subj: DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS) FOR OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT (WWTP) AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR, HAWAII

Thank you for your written comments of December 4, 1997, regarding the DEIS for the above referenced action. Our responses to your comments are as follows:

Comment: Please verify the data listing on Table 4.4-5, "Nutrient Levels (in mg/l) and Flow Rate of Wastewater Effluent from Three Treatment Plants" on page 4-28 of the subject document. The flow rate at Sand Island WWTP and Honouliuli Wastewater Treatment Plant are 78 million gallons per day (mgd) and 26 to 27 mgd, respectively.

Response: Table 4.4-5 on page 4-28 is footnoted to show that the data listed was obtained from a report entitled, "Pollutant Source Identification," which was published as part of the *Mamala Bay Study, Final Report*. This data was also used for the time-integrated plume modeling that was performed for this particular project and evaluated in the DEIS.

Revision to the DEIS: A note has been added at the end of Table 4.4-5 which states, "The flow rates indicated above represent the flow rates available at the time the modeling study was performed and differ from the flow rates currently on record."

Due to discovery of a soft-soil condition along the original outfall alignment proposed in the DEIS, a new alignment around the soft spot is being designed. A supplemental draft environmental impact statement (SDEIS) will be issued in the fall of this year to cover the new engineering challenge. All recipients of the original DEIS will remain on the distribution list to receive the SDEIS and other subsequent documents related to the EIS.

Should you have any questions, please contact Mr. Gary Kasaoka (Code 231GK) at 471-9338 or by facsimile transmission at 474-5909.

Sincerely,

Melvin N. Kaku
MELVIN N. KAKU
Director
Environmental Planning Division

Copy to:
Belt Collins Hawaii
680 Ala Moana Boulevard, 1st Floor
Honolulu, HI 96813

BOARD OF WATER SUPPLY

CITY AND COUNTY OF HONOLULU
630 SOUTH BERETANIA STREET
HONOLULU, HAWAII 96843
PHONE (808) 527-6180
FAX (808) 533-2714

December 5, 1997

Mr. Gary Kasaoka (Code 231GK)
Pacific Division
Naval Facilities Engineering Command
Pearl Harbor, Hawaii 96860-7300

Dear Mr. Kasaoka:

Subject: Your Transmittal of November 12, 1997 of the Draft Environmental Impact Statement for the Fort Kamehameha Wastewater Treatment Plant Outfall Replacement, Honolulu, Oahu, Hawaii, Offshore of TMK: 9-9-01: 13

Thank you for the opportunity to review and comment on the Draft Environmental Impact Statement for the proposed sewage outfall replacement project.

We have no objections to the proposed project. We have no water system facilities in the project area.

If you have any questions, please contact Barry Usagawa at 527-5235.

Very truly yours,

FOR RAYMOND H. SATO
Manager and Chief Engineer

97 DEC 9 P1:08

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
(MAKALAPA, HI)
PEARL HARBOR, HAWAII 96860-7300

5090P.1F3C
Ser 231/ 1581
23 APR 1998

Mr. Raymond Sato
Board of Water Supply
City and County of Honolulu
630 South Beretania Street
Honolulu, HI 96813

Dear Mr. Sato:

Subj: DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS) FOR OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR, HAWAII

Thank you for your letter of December 5, 1997, regarding the DEIS for the above referenced action. We acknowledge your assessment that the Board of Water Supply has no water system facilities in the project area that could be impacted by the proposed action and that you have no objections to the project.

Due to discovery of a soft-soil condition along the original outfall alignment proposed in the DEIS, a new alignment around the soft-soil area is being designed. A supplemental draft environmental impact statement (SDEIS) will be issued in the fall of this year to cover the new outfall alignment. All recipients of the original DEIS will remain on the distribution list to receive the SDEIS and other subsequent documents related to the EIS.

Should you have any questions, please contact Mr. Gary Kasaoka (Code 231GK) at 471-9338 or by facsimile transmission at 474-5909.

Sincerely,

MELVIN N. KAKU
Director
Environmental Planning Division

Copy to:
Belt Collins Hawaii
680 Ala Moana Boulevard, 1st Floor
Honolulu, HI 96813-5406

DEPARTMENT OF LAND UTILIZATION
CITY AND COUNTY OF HONOLULU
650 SOUTH KING STREET, 7TH FLOOR • HONOLULU, HAWAII 96813
PHONE: (808) 523-4414 • FAX: (808) 527-6743

JEREMY HARRIS
MAYOR

JAN NAOE SULLIVAN
DIRECTOR

LORETTA K.C. CHEE
DEPUTY DIRECTOR

97-08604(DT)
'97 EA Comments Zone 9

December 9, 1997

Mr. Gary Kasaoka
Department of the Navy
Pacific Division
Naval Facilities Engineering Command
Pearl Harbor, Hawaii 96860-7300

Dear Mr. Kasaoka:

Draft Environmental Impact Statement (DEIS)
Proposed Outfall Replacement
Wastewater Treatment Plant (WWTP) at Fort Kamehameha

The above proposal will replace the existing outfall, which discharges treated wastewater effluent into the Pearl Harbor Entrance Channel.

The WWTP property is zoned F-1 Military and Federal Preservation District. All military and federal uses and structures are permitted within the F-1 District, and are not regulated by the City's Land Use Ordinance.

We have no further comment as the proposal must obtain other governmental approvals, such as Section 401 Water Quality Certification and National Pollutant Discharge Elimination System Permits.

Should you have any questions regarding this letter, please contact Ms. Dana Teramoto of our staff at 523-4648.

Very truly yours,

JAN NAOE SULLIVAN
Director of Land Utilization

JNS:am

g:ppd\9708604.djt

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
(MAKALAPA, HI)
PEARL HARBOR, HAWAII 96860-7300

5090P 1F3C
Ser 231/1579

23 APR 1998

Ms. Jan Naoe Sullivan, Director
Department of Land Utilization
City and County of Honolulu
650 South King Street, 7th Floor
Honolulu, HI 96813

Dear Ms. Sullivan:

Subj: DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS) FOR OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR, HAWAII

Thank you for your letter of December 4, 1997, regarding the DEIS for the above referenced action. We acknowledge your assessment that the Wastewater Treatment Plant property is zoned F-1 Military and Federal Preservation District and that all military and federal uses and structures are permitted within the F-1 District. We also understand that the City's Land Use Ordinance does not regulate the proposed action.

Due to discovery of a soft-soil condition along the original outfall alignment proposed in the DEIS, a new alignment around the soft-soil area is being designed. A supplemental draft environmental impact statement (SDEIS) will be issued in the fall of this year to cover the new outfall alignment. All recipients of the original DEIS will remain on the distribution list to receive the SDEIS and other subsequent documents related to the EIS.

Should you have any questions, please contact Mr. Gary Kasaoka (Code 231GK) at 471-9338 or by facsimile transmission at 474-5909.

Sincerely,

Melvin N. Kaku

MELVIN N. KAKU
Director
Environmental Planning Division

Copy to:
Belt Collins Hawaii
680 Ala Moana Boulevard, 1st Floor
Honolulu, HI 96813

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
LAND DIVISION
P.O. BOX 621
HONOLULU, HAWAII 96809

December 11, 1997

LD-NAV
REF.: 2313986.RCM

Stanley Y. Uehara, Acting Director
Environmental Planning Division
Naval Facilities Engineering Command
Pearl Harbor, Hawaii 96860-7300

Dear Mr. Uehara:

SUBJECT: Review : Draft Environmental Impact Statement
File No. : 5090P.1F3C - Ser.: 231/3986
Applicant: Department of the Navy
Project : Outfall Replacement Wastewater Treatment Plant
Location : Fort Kamehameha, Pearl Harbor, Oahu, Hawaii

Thank you for allowing us the opportunity to review the subject Draft Environmental Impact Statement (Summary).

Attached herewith is a copy of our Commission on Water Resource Management's comments related to water resources. Should you have any questions regarding their comments, please feel free to contact Ms. Lenore Nakama at 587-0218.

A Conservation District Use Permit (CDUP), is required for the proposed project. The contact person for the processing of the CDUP is Mr. Sam Lemmo or Mr. Ed Henry of our Land Division's Planning and Technical Services Branch at 587-0386.

Should you have any questions, please feel free to contact Nicholas Vaccaro at 587-0433.

Very truly yours,

DEAN Y. UCHIDA
Administrator

c: At Large Land Board Member
Oahu District Land Office

BENJAMIN J. CAYETANO
GOVERNOR OF HAWAII

DEC 11 10 03 AM '97

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT
P. O. BOX 621
HONOLULU, HAWAII 96809

December 4, 1997

TO: Mr. Dean Uchida, Administrator
Land Division

FROM: Rae M. Loui, Deputy Director
Commission on Water Resource Management (CWRM)

SUBJECT: Draft Environmental Impact Statement
Outfall Replacement Wastewater Treatment Plant
Fort Kamehameha, Pearl Harbor, Oahu, Hawaii

FILE NO.: 5090P.1F3C - Ser 231/3986

Thank you for the opportunity to review the subject document. Our comments related to water resources are marked below.

In general, the CWRM strongly promotes the efficient use of our water resources through conservation measures and use of alternative non-potable water resources whenever available, feasible, and there are no harmful effects to the ecosystem. Also, the CWRM encourages the protection of water recharge areas which are important for the maintenance of streams and the replenishment of aquifers.

[x] We recommend coordination with the county government to incorporate this project into the county's Water Use and Development Plan.

[ ] We are concerned about the potential for ground or surface water degradation/contamination and recommend that approvals for this project be conditioned upon a review by the State Department of Health and the developer's acceptance of any resulting requirements related to water quality.

[ ] A Well Construction Permit and a Pump Installation Permit from the CWRM would be required before ground water is developed as a source of supply for the project.

[ ] The proposed water supply source for the project is located in a designated water management area, and a Water Use Permit from the CWRM would be required prior to use of this source.

[ ] Groundwater withdrawals from this project may affect streamflows. This may require an instream flow standard amendment.

[ ] We recommend that no development take place affecting highly erodible slopes which drain into streams within or adjacent to the project.

[ ] If the proposed project diverts additional water from streams or if new or modified stream diversions are planned, the project may need to obtain a stream diversion works permit and petition to amend the interim instream flow standard for the affected stream(s).

[ ] Based on the information provided, it appears that a Stream Channel Alteration Permit pursuant to Section 13-169-50, HAR will be required before the project can be implemented.

[ ] Based on the information provided, it does not appear that a Stream Channel Alteration Permit pursuant to Section 13-169-50, HAR will be required before the project can be implemented.

[ ] An amendment to the instream flow standard from the CWRM would be required before any streamwater is diverted.

[X] OTHER:

As a general policy, the Commission on Water Resource Management strongly encourages the reasonable and beneficial use of reclaimed water.

The report describes effluent reuse as an alternative that is not preferred based on cost comparison. However, Table 2.5-2 on page 2-49 indicates that the largest cost item is the construction of a desalination plant to bring the chlorides of the treated effluent to acceptable irrigation quality. Because current wastewater treatment facilities at Fort Kamehameha have the potential to produce R-1 quality effluent, blending the water to achieve acceptable salinities would be much less costly, provided that the additional treatment (ie. disinfection) afforded by an RO unit is deemed unnecessary by the Department of Health prior to reuse.

Page 2-4 cites one of the reasons that effluent reuse is not preferred is because sufficient demand might not exist in the area to reuse all the effluent. We would suggest that the report provide an estimate of the nonpotable demand in the vicinity of the wastewater treatment plant, which includes usage at the Honolulu International Airport and several golf courses.

If there are any questions, please contact Lenore Nakama at 587-0218.

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
(MAKALAPA, HI)
PEARL HARBOR, HAWAII 96860-7300

5090P.1F3C
Ser 231/1682
01 MAY 1998

Mr. Dean Y. Uchida
Land Division Administrator
Department of Land and Natural Resources
P.O Box 621
Honolulu, HI 96809

Dear Mr. Uchida:

Subj: DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS) FOR OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT (WWTP) AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR, HAWAII

Thank you for your written comments of December 11, 1997 and those from the Commission on Water Resource Management of December 4, 1997, on the DEIS for the above referenced action. Our response to comments from the Land Division and the Commission on Water Resource Management are as follows:

Land Division

Comment: A Conservation District Use Permit (CDUP) is required for the proposed project.

Response: Since the affected areas are federally owned lands, a CDUP is not required for the proposed project.

Revision of the DEIS: None.

Commission on Water Resource Management

Comment: We recommend coordination with the county government to incorporate this project into the county's Water Use and Development Plan.

Response: The Navy's decision to coordinate with the City and County of Honolulu to incorporate this project into their Water Use and Development Plan is yet to be determined and is beyond the scope of this document.

Revision of the DEIS: None.

Comment: As a general policy, the Commission on Water Resource Management strongly encourages the reasonable and beneficial use of reclaimed water.

Response: As stated in Section 2.5.2.3, the outfall construction does not preclude future effluent reuse. The outfall would be useful for disposal of brine and excess or off-specification effluent. In addition, according to Section 2.5.1.1, "best

case" assumptions were incorporated into the reuse alternative. Until the desalination problem can be solved economically or the value of reclaimed water increases dramatically, reuse of effluent from the WWTP at Fort Kamehameha cannot be considered a financially practicable alternative.

Revision of the DEIS: None

Comment: The report describes effluent reuse as an alternative that is not preferred based on cost comparison. However, Table 2.5-2 on page 2-49 indicates that the largest cost item is the construction of a desalination plant to bring the chlorides of the treated effluent to acceptable irrigation quality. Because current wastewater treatment facilities at Fort Kamehameha have the potential to produce R-1 quality effluent, blending the water to achieve acceptable salinity would be much less costly, provided that the additional treatment (i.e., disinfection) afforded by an reverse osmosis unit is deemed unnecessary by the Department of Health prior to reuse.

Response: As stated in the second paragraph of Section 2.5, the salinity of the effluent could be reduced through dilution with freshwater, but it would require approximately 490,000 cubic meters per day (m^3/day) (130 million gallons per day [mgd]) of freshwater to reduce effluent salinity to a level acceptable for irrigation. Since the nonpotable water demand for the entire island of Oahu was 485,000 m^3/day (128 mgd) in 1990, dilution is considered impractical.

Revision of the DEIS: None.

Comment: Page 2-4 cites one of the reasons that effluent reuse is not preferred is because sufficient demand might not exist in the area to reuse all the effluent. We would suggest that the report provide an estimate of the nonpotable demand in the vicinity of the wastewater treatment plant, which includes usage at the Honolulu International Airport and several golf courses.

Response: As stated in Section 2.5.1.1, the estimated nonpotable water demand for the Hickam Golf Course, Hickam Par 3 Golf Course, and Navy-Marine Golf Course is 3,000 m^3/day (0.8 mgd) each. The Honolulu International Airport requires approximately 36,000 m^3/d (9.5 mgd) of irrigation water. Even though these numbers imply there is sufficient demand for reclaimed water, we anticipate that the Honolulu International Airport and the golf courses would prefer to purchase less expensive nonpotable water available from the Board of Water Supply, leaving the Navy without a way to dispose of the desalinated, reclaimed water.

Revision of the DEIS: The statement on page 2-4 will be revised to read, "Sufficient demand might not exist in the area to reuse all of the effluent from the

Subj: DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS) FOR OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT (WWTP) AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR, HAWAII

WWTP at Fort Kamehameha because of existing, less expensive sources of nonpotable water."

Due to discovery of a soft-soil condition along the original outfall alignment proposed in the DEIS, a new alignment around the soft spot is being designed. A supplemental draft environmental impact statement (SDEIS) will be issued in the fall of this year to cover the new engineering challenge. All recipients of the original DEIS will remain on the distribution list to receive the SDEIS and other subsequent documents related to the EIS

Should you have any questions, please contact Mr. Gary Kasaoka (Code 231GK) at 471-9338 or by facsimile transmission at 474-5909.

Sincerely,

Melvin N. Kaku

MELVIN N. KAKU
Director
Environmental Planning Division

Copy to:
Belt Collins Hawaii
680 Ala Moana Boulevard, 1st Floor
Honolulu, HI 96813

BENJAMIN J. CAYETANO
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF HEALTH
P.O. BOX 3378
HONOLULU, HAWAII 96801

LAWRENCE MIIKE
DIRECTOR OF HEALTH

In reply, please refer to:
EMD / WB

971494
09-09.W2

December 17, 1997

Mr. Stanley Y. Uehara
Acting Director
Environmental Planning Division
Department of the Navy
Pacific Division
Naval Facilities Engineering Command
Makalapa, Hawaii
Pearl Harbor, Hawaii 96860-7300

Dear Mr. Uehara:

Subject: **Draft Environmental Impact Statement (DEIS) for Proposed Outfall Replacement for Wastewater Treatment Plant at Fort Kamehameha**
Naval Public Works Center
Pearl Harbor, Hawaii

We have reviewed the draft environmental impact statement (DEIS) for the proposed outfall replacement for wastewater treatment plant at Fort Kamehameha. At this time, we have no comments to offer. We are pleased with the replacement of the wastewater outfall which will hopefully improve our nearshore water quality conditions. Efforts should also be made to coordinate these efforts with our Clean Water Branch and their permit activities.

All wastewater plans must conform to applicable provisions of the Department of Health's Administrative Rules, Chapter 11-62, "Wastewater Systems." We do reserve the right to review the detailed wastewater plans for conformance to applicable rules.

Should you have any further questions, please contact Mr. Harold Yee of the Wastewater Branch at telephone 586-4294.

Sincerely,

DENNIS TULANG, ~~P.E.~~
Chief, Wastewater Branch

LK:erm

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
(MAKALAPA, HI)
PEARL HARBOR, HAWAII 96860-7300

5090P.1F3C
Ser 231/ 1794
7 MAY 1998

Mr. Dennis Tulang, P.E., Chief
Department of Health Wastewater Branch
State of Hawaii
P.O. Box 3378
Honolulu, HI 96801

Dear Mr. Tulang:

Subj: DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS) FOR OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR, HAWAII

Thank you for your comments of December 17, 1997, on the DEIS for the above referenced proposed action. We understand that you have no comments to offer at this time and that you reserve the right to review the detailed wastewater plans at some later date for conformance to applicable rules. Your suggestion that we should coordinate with the Department of Health Clean Water Branch regarding their permit requirements is well taken.

Due to discovery of a soft-soil condition along the original outfall alignment proposed in the DEIS, a new alignment around the soft spot is being designed. A supplemental draft environmental impact statement (SDEIS) will be issued in the fall of this year to cover the new engineering challenge. All recipients of the original DEIS will remain on the distribution list to receive the SDEIS and other subsequent documents related to the EIS.

Should you have any questions, please contact Mr. Gary Kasaoka (Code 231GK) at 471-9338 or by facsimile transmission at 474-5909.

Sincerely,

MELVIN N. KAKU
Director
Environmental Planning Division

Copy to:
Belt Collins Hawaii
680 Ala Moana Boulevard, 1st Floor
Honolulu, HI 96813

STATE OF HAWAI'I
OFFICE OF HAWAIIAN AFFAIRS
711 KAPI'OLANI BOULEVARD, SUITE 500
HONOLULU, HAWAI'I 96813-5249
PHONE (808) 594-1888
FAX (808) 594-1865

December 19, 1997

Mr. Stanley Uehara, Director
Environmental Planning Division
Department of the Navy
Naval Facilities Engineering Command
Pearl Harbor, HI 96860-7300

Subject: Draft Environmental Impact Statement (DEIS) for Outfall Replacement for Wastewater Treatment Plant at Fort Kamehameha, Navy Public Works Center, Pearl Harbor, Island of Oahu

Dear Mr. Uehara:

Thank you for the opportunity to review the DEIS for Outfall Replacement for Wastewater Treatment Plant (WWTP) at Fort Kamehameha, Pearl Harbor. The Naval Public Works Center proposes to construct a 2.4-mile, 42 inch-diameter outfall pipe terminating in a 200-meter diffuser at a depth of 150 feet into the open coastal waters offshore of Fort Kamehameha. This new pipeline will replace existing WWTP effluent discharger thus eliminating limitations and violations associated with effluent disposal into the Pearl Harbor Estuary.

The Office of Hawaiian Affairs (OHA) has no objections at this time to the proposed project. Based on information contained in the DEIS, the 2.4 mile discharger will dispose effluent into deep ocean waters away from the Pearl Harbor Estuary. This action alone will bring significant positive impacts on water quality, marine biota, and public health in the Pearl Harbor Estuary.

But OHA is concerned that without proper mechanisms guiding safe effluent disposal, the proposed off-shore effluent discharge will merely shift wastewater hazards from the estuary to open coastal waters. OHA is particularly concerned about potential impacts on endangered species, recreational and fishing activities, marine life, and overall public health in the area of discharge. Furthermore, although the DEIS indicates no presence of cultural resources along the proposed pipeline, OHA urges the preparers to notify OHA and the State Historic Sites Division in the event that cultural resources are uncovered during excavation activities.

Please contact Colin Kippen (594-1938), Officer of the Land and Natural Resources Division, or Luis A. Manrique (594-1758), should you have any questions on this matter.

Sincerely yours,

Randall Ogata
Administrator

Colin Kippen
Officer,
Land and Natural
Resources Division

cc Board of Trustees

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
(MAKALAPA, HI)
PEARL HARBOR, HAWAII 96860-7300

5090P 1F3C
Ser 231/ 2287

16 JUN 1998

Mr. Randall Ogata
Mr. Colin Kippen
Office of Hawaiian Affairs
711 Kapiolani Boulevard, Suite 500
Honolulu, HI 96813-5249

Dear Messrs. Ogata and Kippen:

Subj: DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS) FOR OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT (WWTP) AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR

Thank you for your letter of December 19, 1997, in which you offered comments following your review of subject document. Although the Office of Hawaiian Affairs (OHA) had no objections to the proposed project and even recognized the potential for significant positive impacts on water quality, marine biota, and public health in the Pearl Harbor Estuary, your agency nevertheless had some concerns on the project which you proceeded to highlight. Our responses to those concerns and your comments are provided below:

Comment: OHA is concerned that without proper mechanisms guiding safe effluent disposal, the proposed off-shore effluent discharge will merely shift wastewater hazards from the estuary to open coastal waters. OHA is particularly concerned about potential impacts on endangered species, recreational and fishing activities, marine life, and overall public health in the area of the discharge.

Response: As indicated in Section 1.4, the WWTP at Fort Kamehameha has recently been expanded to include secondary treatment with anoxic basins to improve sludge settling characteristics, sand filtration to improve suspended solids removal, and ultraviolet disinfection to improve pathogen destruction prior to effluent discharge. The existing level of treatment is expected to result in the discharge of high quality effluent. Relocation of the discharge is intended to remove the nutrient loading of the discharge from the Pearl Harbor Estuary, which is designated a Water Quality Limited Segment. The Open Coastal Waters of Mamala Bay have a much greater capability of assimilating the nutrients contained in the effluent, and provide improved mixing and dilution of the effluent upon discharge. On this basis, the Navy feels that the combination of the recent WWTP upgrade and the proposed outfall will ensure safe effluent disposal and the protection of public health, the ecosystem in the vicinity of the proposed outfall (including endangered species), and activities which depend upon this ecosystem.

Revision to DEIS: None.

Comment: OHA urges the preparers to notify OHA and the State Historic Sites Division in the event that cultural resources are uncovered during excavation activities.

Response: In the event that cultural resources are uncovered during the excavation activities, OHA the State Historic Preservation Office, Hui Malama I Na Kapuna O Hawaii Nei, and the Oahu Island Burial Council will be notified.

Revision to DEIS: None.

5090P 1F3C
Ser 231/ 2287

Should you have any questions, please contact Mr. Gary Kasaoka (Code 231GK) at 471-9338 or by facsimile transmission at 474-5909.

Sincerely,

Melvin N. Kaku
MELVIN N. KAKU
Director
Environmental Planning Division

Copy to:
Belt Collins Hawaii
680 Ala Moana Boulevard, First Floor
Honolulu, HI 96813

DEPARTMENT OF THE ARMY
U. S. ARMY ENGINEER DISTRICT, HONOLULU
FT. SHAFTER, HAWAII 96858-5440

REPLY TO ATTENTION OF

CEPOD-ET-PP (200) 19 December 1997

MEMORANDUM FOR COMMANDER, PACIFIC DIVISION, NAVAL FACILITIES ENGINEERING COMMAND, ATTN: ENVIRONMENTAL PLANNING DIVISION, PEARL HARBOR, HI 96860-7300

SUBJECT: Draft Environmental Impact Statement (DEIS) for Proposed Outfall Replacement for Wastewater Treatment Plant at Fort Kamehameha, Navy Public Works Center, Pearl Harbor, Hawaii

1. Reference letter 5090P.IF3C, Ser 231/3986, dated 12 November 1997, SAB.

2. The following comments are provided:

a. We acknowledge that the project will require a Department of the Army permit as stated on page 2-10 of the DEIS. For further permit information, please contact our Regulatory Section at 438-9258 (extension 14) and refer to file number 960000384.

b. The flooding and tsunami inundation information provided on page 4-4 of the DEIS is correct.

FOR THE COMMANDER:

James A. Nakamura

RAY H. JYO, P.E.
Director of Engineering
and Technical Services

5090P.1F3C
Ser 231/1852

13 MAY 1998

From: Commander, Pacific Division, Naval Facilities Engineering Command
To: Commander, U.S. Army Engineer District, Honolulu (CEPOD-ET-PP)

Subj: DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS) FOR OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR, HAWAII

Ref: (a) USAED Honolulu memo CEPOD-ET-PP (200) of 19 Dec 97

1. In response to reference (a) regarding the DEIS for the above referenced action, we will be submitting the permit application to the Regulatory Section under file number 960000384 when ready. We are pleased with your comment that the flooding and tsunami inundation information provided on page 4-4 of the DEIS is correct.

2. Due to discovery of a soft-soil condition along the original outfall alignment proposed in the DEIS, a new alignment around the soft spot is being designed. A supplemental draft environmental impact statement (SDEIS) will be issued in the fall of this year to cover the new engineering challenge. All recipients of the original DEIS will remain on the distribution list to receive the SDEIS and other subsequent documents related to the EIS.

3. Should you have any questions, please contact Mr. Gary Kasaoka (Code 231GK) at 471-9338 or by facsimile transmission at 474-5909.

MELVIN N. KAKU
By direction

Copy to:
Belt Collins Hawaii
680 Ala Moana Boulevard, First Floor
Honolulu, HI 96813

Blind copy to:
231GK

w:\231GK\doa.doc

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

December 30, 1997

Mr. Gary Kasaoka, Code 231
Pacific Division, Naval Facilities Engineering Command
Pearl Harbor, Hawaii 96860-7300

Dear Mr. Kasaoka:

The U.S. Environmental Protection Agency (EPA) has reviewed the Draft Environmental Impact Statement (DEIS), **Outfall Replacement for Wastewater Treatment Plant at Fort Kamehameha, Navy Public Works Center, Pearl Harbor, Hawaii.** Our comments are provided pursuant to the National Environmental Policy Act (NEPA), the Council on Environmental Quality's NEPA Implementation Regulations at 40 CFR 1500-1508, and Section 309 of the Clean Air Act.

The DEIS analyzes the impacts of replacing an existing outfall for effluent discharge from the Wastewater Treatment Plant (WWTP) at Fort Kamehameha. The proposed action, and Navy's preferred alternative, is to construct a new effluent outfall into the open coastal water offshore of Fort Kamehameha. This would entail construction of a 2.4 mile-long, 42 inch-diameter outfall pipe terminating in a 656 foot-long diffuser at a depth of 150 feet. The DEIS also analyzes the alternatives of upland disposal of effluent by subsurface injection, effluent reuse, and no action.

We have rated this DEIS as EC-2 -- Environmental Concerns-Insufficient Information. (See the enclosed "Summary of Rating Definitions and Follow-up Action"). Our rating primarily reflects concerns about potential impacts to aquatic resources and the need for additional information on the affected environment. Our comments are intended to insure that, in the spirit of NEPA, the project proceeds in an environmentally sound manner and discloses all significant potential impacts and relevant existing conditions to the public. Items specifically addressed, and forming the main basis for our rating, include:

- Need for amplification of baseline conditions and a more thorough treatment of potential cumulative impacts.

- Recommended improvements to the DEIS in the area of methodology and scientific integrity, e.g. discussion of trace metals in the WWTP effluent.

- Questions regarding applicability of a CWA 404(b)(1) alternatives analysis, and lack of

a final outfall construction design plan.

- Need for further discussion of alternatives considered but eliminated.

Our detailed comments are enclosed. We appreciate the opportunity to review this DEIS. Please send two copies of the FEIS to this office at the letterhead address (mail code CMD-2) when it is officially filed with our Washington, D.C., office. Should you have any questions, please contact me at (415) 744-1584, or Karl Kanbergs at (415) 744-1483.

Sincerely,

David J. Farrel, Chief
Federal Activities Office

003004/97-357

Enclosure

SUMMARY OF RATING DEFINITIONS AND FOLLOW-UP ACTION

Environmental Impact of the Action

LO-Lack of Objections

The EPA review has not identified any potential environmental impacts requiring substantive changes to the proposal. The review may have disclosed opportunities for application of mitigation measures that could be accomplished with no more than minor changes to the proposal.

EC-Environmental Concerns

The EPA review has identified environmental impacts that should be avoided in order to fully protect the environment. Corrective measures may require changes to the preferred alternative or application of mitigation measures that can reduce the environmental impact. EPA would like to work with the lead agency to reduce these impacts.

EO-Environmental Objections

The EPA review has identified significant environmental impacts that must be avoided in order to provide adequate protection for the environment. Corrective measures may require substantial changes to the preferred alternative or consideration of some other project alternative (including the no action alternative or a new alternative). EPA intends to work with the lead agency to reduce these impacts.

EU-Environmentally Unsatisfactory

The EPA review has identified adverse environmental impacts that are of sufficient magnitude that they are unsatisfactory from the standpoint of environmental quality, public health or welfare. EPA intends to work with the lead agency to reduce these impacts. If the potential unsatisfactory impacts are not corrected at the final EIS stage, this proposal will be recommend for referral to the Council on Environmental Quality (CEQ).

Adequacy of the Impact Statement

Category 1-Adequate

EPA believes the draft EIS adequately sets forth the environmental impact(s) of the preferred alternative and those of the alternatives reasonably available to the project or action. No further analysis or data collection is necessary, but the reviewer may suggest the addition of clarifying language or information.

Category 2-Insufficient Information

The draft EIS does not contain sufficient information for EPA to fully assess environmental impacts that should be avoided in order to fully protect the environment, or the EPA reviewer has identified new reasonably available alternatives that are within the spectrum of alternatives analyzed in the draft EIS, which could reduce the environmental impacts of the action. The identified additional information, data, analyses, or discussion should be included in the final EIS.

Category 3-Inadequate

EPA does not believe that the draft EIS adequately assesses potentially significant environmental impacts of the action, or the EPA reviewer has identified new, reasonably available alternatives that are outside of the spectrum of alternatives analyzed in the draft EIS, which should be analyzed in order to reduce the potentially significant environmental impacts. EPA believes that the identified additional information, data, analyses, or discussions are of such a magnitude that they should have full public review at a draft stage. EPA does not believe that the draft EIS is adequate for the purposes of the NEPA and/or Section 309 review, and thus should be formally revised and made available for public comment in a supplemental or revised draft EIS. On the basis of the potential significant impacts involved, this proposal could be a candidate for referral to the CEQ.

*From: EPA Manual 1640, "Policy and Procedures for the Review of Federal Actions Impacting the Environment."

NATIONAL ENVIRONMENTAL POLICY ACT (NEPA)

AFFECTED ENVIRONMENT

Most of EPA's concerns focus on potential project impacts to the marine aquatic environment. We suggest that the FEIS provide additional information describing the affected environment, direct, indirect and cumulative impacts. The Navy should improve the DEIS in the area of methodology and scientific integrity according to guidance provided by CEQ Regulations at 40 CFR 1502.24. The perceived lack of significant impacts from the project should not preclude a thorough description of the affected environment or cumulative impacts, because such description if very relevant to the purpose of EIS preparation [40 CFR 1502.1] and the project permitting process.

Existing Environmental Degradation
The DEIS documents environmental degradation of Mamala Bay. Appendix IX of the DEIS (pg. 23) states that "the entire reef complex has received considerable disturbance over the last 100 years including dredging and filling, high nutrient loading from point sources and numerous non-point source inputs from urban and industrial areas of Honolulu." However, sections of the document and its appendices indicate that certain portions of the ecosystem may be stable. On page 21 of the same appendix, it is suggested that benthic marine communities have been relatively stable over the past 24 years (based on qualitative observations). Additional baseline information describing the affected environment should be included in the FEIS and carried through in treatment of potential significant cumulative impacts (please refer to our comments on cumulative impacts). We believe that ample information may be available, such as the referenced Mamala Bay Study (MBS), and work by the US Geological survey for this purpose. With regard to incomplete or unavailable information, please refer to 40 CFR 1502.22. The FEIS should generally describe the magnitude and chemistry (including trace metals and other potential toxins such as pesticides and industrial-related organic compounds) of the point source and non point source discharges effecting the outer Pearl Harbor estuary and proposed outfall pipe placement. Specific documented changes to components of the marine environment, such as the reef flats should be described under cumulative impacts.

Marine Ecosystem
Additional data and clarification are required for sufficient description of the marine ecosystem along the proposed outfall pipe route and zone of mixing (ZOM). In particular, the affected marine life in the zone of mixing should be summarized in the body of the FEIS. Appendix IX, an Assessment Report of the Biologic Communities in the Vicinity of the Proposed Sewer Outfall, describes the various biotopes. However, the included maps in that report do not show the proposed outfall pipe alignment We suggest that chapter 3 incorporate a summary description of the various biotopes and an easily read map, showing the various biotope

communities and the proposed outfall pipe location, similar in style to Figure 3.4-1. This information should assist both in the NEPA decision making process and outfall construction design.

Characterization of Effluent Chemistry and Discussion of Trace Metal Distribution
The WWTP treats both domestic and industrial wastewater flows (pg. 1-10). Trace metal chemistry or other potential toxicity of the effluent is not described in the DEIS, although characterization of nutrients, suspended solids, and bacteria is well documented. Clearly, during the NPDES permitting process, water quality standards for toxics will be addressed; however, for purposes of public disclosure and relevance to discussion of marine life, the Navy should provide additional data in the FEIS. A typical complete effluent analysis should be given, and contrasted against applicable water quality standards. Anticipated or documented variations in listed concentrations should be described. Furthermore, the FEIS should provide annual end-of-pipe anticipated discharges in pounds/year of trace metals, including but not limited to As, Cd, Cr, Cu, Fe, Pb, and Zn. The Navy should summarize data on marine floor sediment content of anthropogenic toxins, and bioaccumulation of metals within Mamala Bay for purposes of establishing a baseline from which to gauge future impacts.

ALTERNATIVE ANALYSIS

The Pollution Prevention Act of 1990 established that it is the national policy of the United States that, whenever feasible, pollution should be reduced or prevented at the source, and that disposal or other release of pollutants into the environment should be employed only as a last resort. EPA therefore questions the rather hasty elimination of a WWTP facility upgrade alternative. CEQ regulations require a discussion of alternatives considered but eliminated [40 CFR 1502.14(a)] and typically most EIS's include a separate section on this subject. On page 1-4 of the DEIS, in a very short paragraph, the alternative of upgrading existing facilities is eliminated, citing lack of space and cost (estimated to be $59 million); yet, the DEIS analyses, in detail, an effluent reuse alternative that has an estimated 30-year life cycle cost of $117,160,000. The Navy should demonstrate in the FEIS why upgrading the facilities shouldn't be the environmentally preferred alternative, and why truly there is lack of space (this is not readily apparent from enclosed maps). EPA commends the Navy on a thorough job in treatment of the upland disposal and reuse alternatives.

CLEAN WATER ACT (CWA) SECTION 404 PERMIT AND ALTERNATIVE OUTFALL ALIGNMENTS

For the ocean disposal alternative (the proposed action), the Navy states that a Section 404 Clean Water Act permit will be required, as issued by the US Army Corps of Engineers (Corps). It is not indicated whether this would be an individual permit. In those situations where an individual

section 404 permit is applicable, an alternatives analysis, under CWA 404(b)(1), should be integrated into the NEPA process. Pursuant to CWA 404(b)(1) guidelines at 40 CFR 230, practicable alternatives to the proposed disturbance must be examined and the physical and chemical components of the candidate site must be evaluated. Furthermore, 404(b)(1) guidelines provide for the protection of several "special aquatic sites," including coral reefs. The proposed outfall pipe crosses coral reefs. Therefore, the outfall alignment should receive special consideration. EPA acknowledges Navy's statement that construction impacts will not directly affect a large area of living coral; however, the FEIS should document why the selected preferred alignment is the least damaging practicable alternative. We found Navy's reasoning why the new outfall could not be constructed across the reef flat along the same location as the old outfall insufficient. The FEIS should contain clarification on this issue.

OUTFALL PIPE CONSTRUCTION

The DEIS describes alternative construction methods and potential environmental impacts for the proposed outfall pipe, and notes that a final construction design plan has not been completed. Alternative proposed construction methods include open trenching, directional drilling and underground boring. Impacts such as silting, noise and physical surface disturbance will vary significantly, depending on the final choice or combination of methods. As written, the DEIS may be viewed as a broad and general document. EPA recommends that the FEIS state that additional NEPA documentation will apply, once final design plans are finished and proper consultation with the Corps has been completed. Additional supplemental NEPA documents should be tiered off the current EIS [40 CFR 1508.28(b)].

ENVIRONMENTAL CONSEQUENCES AND MITIGATION/MONITORING

Potential significant environmental impacts resulting from the project may be grouped into construction related impacts and operational impacts. In turn, long-term operational impacts have bearing on (future) cumulative impacts. The severity of an impact will, of course, vary depending on construction methods and final outfall pipe alignment and configuration.

Construction Impacts
EPA has several questions about possible construction impacts. The DEIS indicates that impacts to marine life from construction noise will not be significant, citing that certain animals are actually attracted to noises and that the harbor can generally be very noisy from ship traffic. We recommend that the Navy use a more scientific approach to describe potential noise or other physical construction-related impacts to marine life, in particular the endangered green sea turtle. We are concerned about possible noise and vibration impacts from spudding and pile driving to marine life. Furthermore, within the shallow environment, the Navy notes that silt curtains will be used to mitigate against turbidity impacts. The FEIS should describe some of the

other best management practices (BMP's) to reduce construction-related impacts to reef-related biota. We are particularly concerned about potential fuel oil or hydraulic fluid spills related to construction activities. The document should also describe any anticipated impacts and mitigation plans associated with storm events. Depending on construction method chosen, turbidity plumes in deeper waters may be unavoidable, and appear to be sizeable, especially in the "Rock Zone," as shown on Figure 4.4-3. The Navy should amplify its description of potential negative impacts to marine biota from resulting turbidity in this zone. We are also concerned about the turbidity plume affecting the reef zone during storm events, or other unusual current conditions that could move the plume shoreward.

Operational Impacts

We have some general questions about operational impacts from the proposed outfall pipe. In the DEIS there is reference to sea turtles commonly being seen in the vicinity of the existing outfall pipe, and at the diffuser location. The document concludes that the turtles may also occupy the new site. The DEIS states (pg. 4-30) that "... relocation of this nutrient source is not expected to cause negative environmental impacts." However, it does not say why. Because the proposed new pipe and diffuser are in a different physical location and different marine environment, it is may be premature to conclude that significant impacts to the marine life, in general, could not occur from the new operations. The FEIS should justify Navy's assertion that the discharge to open coastal waters (class A) would not have significant impacts to marine life. The FEIS should also provide discussion of any expected thermal-related impacts (what is the difference between the effluent temperature and ocean temperatures and would there be any negative impact to marine life?), and impacts associated with discharge of brackish waters into open coastal waters

The effluent plume modelling, included as appendix VII, appears to generally be a good report. However, the model makes a number of assumptions, including a uniform current. The NAVY should provide additional information on any anticipated environmental impacts from storm conditions or other unusual conditions not addressed by the model.

Monitoring

The FEIS should include monitoring provisions designed to ensure that all recommended mitigation and BMP's are complied with. Furthermore, the role of various agencies in the monitoring oversight of discharge permit compliance should be discussed. The Navy should discuss provisions for long-term monitoring of the effected environment within the ZOM, and larger area of the projected effluent plume.

CUMULATIVE IMPACTS

The FEIS should include additional baseline material, as previously indicated in our comments

entitled, Affected Environment- Existing Environmental Degradation. We suggest that data may be available which describe and summarize the status of the effected environment and recommend that the data be presented in an effective format in the FEIS. Some recent studies have incorporated the concept of "indices of biotic integrity" and use of environmental status maps. As an example, Ranasinghe, et al, 1994 completed a status of benthic communities map as part of a baseline ecological condition study of Chesapeake Bay. The map depicted areal distribution and severity of degradation.

The Navy should expand and enhance its analysis and treatment of cumulative impacts in the FEIS. The DEIS (pg. 4-24) indicates that "the existing outfall accounts for only nine percent of the total estimated water input and about one percent of the estimated solids input into the estuary." Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time [40 CFR 1508.7]. As a further example of ways in which the cumulative impact analysis can be improved, the DEIS notes that at the point of maximum overlap of effluent plumes, cumulative nutrient levels would be increased up to 49 percent above the ambient conditions but would still meet DOA water quality. The conclusion reached is that "... no significant cumulative impacts on water quality will result from the proposed action." It is erroneous to conclude that, just because water quality standards will be met, no significant cumulative impacts will occur. Navy should describe the expected cumulative environmental impacts, in particular to the reef environment, from this cumulative nutrient loading. EPA believes that further evidence justifying Navy's conclusion that the long term discharge of the treated effluent will not be toxic to fish or other aquatic life or create health hazards for the area's recreational users (pg. 4-49) is necessary. Our previously stated concerns regarding trace metals, and potential bioaccumulation need to be addressed here.

In terms of "short term use of the environment v.s. long term productivity," the DEIS states (pg. 4-68): "The ocean's capacity for proper disposal of treated wastewater effluent is a renewable resource. Use of the ocean for disposal of effluent from the WWTP at Fort Kamehameah will have no long-term detrimental effects on the ocean environment or its productivity." We suggest that cumulative effluent disposal, dredging-related activities, and anthropogenic surface water point and non-point source discharges have significantly affected the near shore Mamala Bay environment. As an example, nutrient loading can impact the marine ecosystem and may cause algae blooms, changes in dominant species, and other, perhaps poorly understood, impacts as a "chain" of events. Potential cumulative loading of toxics from the Fort Kamehameaha WWTP and other facilities could have a detrimental effect on the ocean environment. In conclusion, within a framework of sound methodology and scientific integrity, the FEIS should contain a description of the existing negative cumulative impacts to the affected environment and a discussion of potential long-term cumulative impacts from the proposed project and other activities.

ERRORS AND/OR EMISSIONS

EPA has noted a few errors and/or emissions. The document should have an index, as required at 40 CFR 1502.10. The description of outfall alignment erroneously refers to Figure 1.2-2. It should refer to Figure 1.2-3. Regarding reference to Figure 2.3-2 on page 4-27; this figure does not depict distribution of "bottom types."

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
(MAKALAPA, HI)
PEARL HARBOR, HAWAII 96860-7300

5090P.1F3C
Ser 231/2409
25 JUN 1998

Mr. David J. Farrel, Chief
Federal Activities Office
U.S. Environmental Protection Agency, Region IX
75 Hawthorne Street
San Francisco, CA 94105

Dear Mr. Farrel:

Subj: DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS) FOR OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT (WWTP) AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR

Thank you for your letter of December 30, 1997 (Environmental Protection Agency IX Serial 003004/97-357) that provided your agency comments on the DEIS for the above proposed action. Our responses to your comments are provided below.

AFFECTED ENVIRONMENT

Existing Environmental Degradation

Comment: Additional baseline information describing the affected environment should be included in the FEIS and carried through in treatment of potential significant cumulative impacts (please refer to our comments on cumulative impacts). We believe that ample information may be available, such as the referenced Mamala Bay Study, and work by the U.S. Geological Survey for this purpose. With regard to incomplete or unavailable information, please refer to 40 CFR 1502.22.

Response: Mamala Bay is a broad, open reach of coastal ocean water approximately 20 miles wide. The areas of disturbance and relative ecological stability referred to in the DEIS are the areas that could potentially be affected by the project, not Mamala Bay in general. The two primary instruments of effect on the marine environment are: 1) construction, including local and low volume excavation, backfilling, and related sedimentation, and 2) discharge of treated effluent. There is no need to describe material not relevant to potentially affected portions of Mamala Bay. 40 CFR 1502.2 discourages the lengthy discussion of issues that are not relevant to potentially significant impacts.

Revision to the DEIS: None.

Comment: The FEIS should generally describe the magnitude and chemistry (including trace metals and other potential toxins such as pesticide and industrial-related organic compounds) of the point source and non point source discharges effecting [sic] the outer Pearl Harbor estuary and proposed outfall pipe placement. Specific documented changes to components of the marine environment, such as the reef flats should be described under cumulative impacts.

Response: Additional evaluations of the effluent chemistry and the bioaccumulation of toxins in the potentially affected marine environment are being performed.

Revision to the DEIS: The results of these additional evaluations will be included in the FEIS.

Marine Ecosystem

Comment: Additional data and clarification are required for sufficient description of the marine ecosystem along the proposed outfall pipe route and zone of mixing (ZOM). In particular, the affected marine life in the zone of mixing should be summarized in the body of the FEIS.

Response: Additional information regarding the marine ecosystem along the proposed outfall pipe route and ZOM will be provided.

Revision to the DEIS: The additional information on the marine ecosystem will be included in Chapter 4 of the FEIS.

Comment: We suggest that Chapter 3 incorporate a summary description of the various biotopes and an easily read map, showing the various biotope communities and the proposed outfall pipe location, similar in style to Figure 3.4-1.

Response: A map will be provided in the FEIS, which shows the biotic communities observed along the proposed outfall alignment.

Revision to the DEIS: An additional figure will be added to Chapter 3.

Characterization of Effluent Chemistry and Discussion of Trace Metal Distribution

Comment: Trace metal chemistry or other potentially toxic components of the effluent are not described in the DEIS, although characterization of nutrients, suspended solids, and bacteria is well documented. Clearly, during the NPDES permitting process, water quality standards for toxics will be addressed; however, for purposes of public disclosure and relevance to discussion of marine life, the Navy should provide additional data in the FEIS. A typical complete effluent analysis should be given, and contrasted against applicable water quality standards. Anticipated or documented variations in listed concentrations should be described. Furthermore, the FEIS should provide annual end-of-pipe anticipated discharges in pounds/year of trace metals, including but not limited to As, Cd, Cr, Cu, Fe, Pb, and Zn. The Navy should summarize data on marine floor sediment content of anthropogenic toxins and bioaccumulation of metals within Mamala Bay, for purposes of establishing a baseline from which to gauge future impacts.

Response: Effluent concentrations of specific criteria pollutants for Pearl Harbor Estuary are presented in Section 4.4.1.3. To determine the impact of trace metals or other toxic constituents, which are listed in DOH regulations (Hawaii Administrative Rules (HAR) 11-54-04), screening was performed using whole effluent toxicity test results (see Table 4.4-12). It was determined that exposure to undiluted effluent had no quantifiable effect on test species over a period of sampling events. For the purposes of the EIS, there is no apparent acute toxicity effect that requires more detailed analysis. (It is anticipated that monitoring and sampling for certain toxic metals or components may be required pursuant to a discharge permit under the CWA, as implemented by HAR Chapter 11-55.) Additional

information regarding specific contaminants of concern found in the effluent and their bioaccumulation potential in the marine environment will be included in the FEIS (see response to the second comment made on "Existing Environmental Degradation," above).

Revision to the DEIS: Chapter 4 will be revised to include information regarding specific contaminants of concern found in the effluent and their bioaccumulation in the marine environment.

ALTERNATIVE ANALYSIS

Comment: The Pollution Prevention Act of 1990 established that it is the national policy of the United States that, whenever feasible, pollution should be reduced or prevented at the source, and that disposal or other release of pollutants into the environment should be employed only as a last resort. EPA therefore questions the rather hasty elimination of a WWTP facility upgrade alternative. CEQ regulations require a discussion of alternatives considered but eliminated (40 CFR 1502.14(a)) and typically most EIS's include a separate section on this subject. On page 1-4 of the DEIS, in a very short paragraph, the alternative of upgrading existing facilities is eliminated, citing lack of space and cost (estimated to be $59 million); yet, the DEIS analyzes, in detail, an effluent reuse alternative that has an estimated 30-year life cycle cost of $117,160,000. The Navy should demonstrate in the FEIS why upgrading the facilities should not be the environmentally preferred alternative, and why there is lack of space (this is not readily apparent from enclosed maps).

Response: 40 CFR 1502.14(a) states, "…for alternatives which were eliminated from detailed study, briefly discuss the reasons for their having been eliminated." Plant expansion to increase the treatment level was rejected early in the process due to cost and lack of contiguous space. In addition, the wastewater treatment plant adjoins an area containing numerous human burials that needs to be avoided, if possible. (This latter item will be added to Section 1.2.) Plant expansion is an alternative that would reduce the biological loading on the estuary, but would not remove the discharge from the Pearl Harbor Estuary. Further justification is not needed. The reuse option could not be dismissed early in the evaluation because of the potential resource value of reclaimed effluent. The value of reuse (equivalent to the avoided cost of using potable groundwater) needed to be compared to the cost of treating and delivering effluent suitable for reuse.

Revision to the DEIS: Section 1.2 will be revised to include more information regarding the elimination of the WWTP facility upgrade alternative.

CWA SECTION 404 PERMIT AND ALTERNATIVE OUTFALL ALIGNMENTS

Comment: For the ocean disposal alternative (the proposed action), the Navy states that a Section 404 CWA permit will be required, as issued by the Army Corps of Engineers (COE). It is not indicated whether this would be an individual permit.

Response: Whether an individual permit is required or coverage under nationwide permit No. 7 is authorized for the outfall structure will be determined in consultation with the COE.

Revision to the DEIS: The type of permit required will be discussed in the FEIS.

Comment: In those situations where an individual section 404 permit is applicable, an alternatives analysis, under CWA 404(b)(1), should be integrated into the National Environmental Policy Act (NEPA) process. Pursuant to CWA 404(b)(1) guidelines at 40 CFR 230, practicable alternatives to the proposed disturbance must be examined and the physical and chemical components of the candidate site must be evaluated. Furthermore, 404(b)(1) guidelines provide for the protection of several "special aquatic sites," including coral reefs. The proposed outfall pipe crosses coral reefs. Therefore, the outfall alignment should receive special consideration. EPA acknowledges the Navy's statement that construction impacts will not directly affect a large area of living coral; however, the FEIS should document why the selected preferred alignment is the least damaging practicable alternative. We found the Navy reasoning why the new outfall could not be constructed across the reef flat along the same location as the old outfall insufficient. The FEIS should contain clarification on this issue.

Response: With regard to 404(b)(1) analysis, the DEIS, as written, is sufficient for considering alternatives as contemplated in 40 CFR part 230, Subpart B, Section 230.10. The DEIS considers both alternatives that do not require discharges (upland disposal and reuse) and other discharge locations. Whether alternatives are practical includes consideration of cost and logistics in light of the project purpose [230.10(a)]. Disposal of fill into marine waters for this project is limited, relatively small in scope compared to surrounding marine biotic communities likely to be affected, and incidental to the purpose of the project. In this regard, none of the prohibitions in 230.10(b) are applicable. State of Hawaii Department of Health (DOH) water quality standards for Pearl Harbor Estuary, specified in HAR Chapter 11-54-05, include turbidity standards, based on the geometric mean over an unspecified series of sampling events (geometric mean of 4.0 NTU, not to exceed 15 NTU more than 2 percent of the time). Anticipated exceedances of water quality turbidity standards are addressed in Section 4.4.1.4 of the DEIS. Turbidity from construction has been modeled without consideration of mitigating measures and will temporarily exceed standard criteria values as shown in Figure 4.4-3. However, these temporary episodes will not, over time, cause exceedances of turbidity standards because of the temporary nature of the discharge and the cumulative nature of the statistical standard. If a Section 404 permit is required, a Section 401 Water Quality Certification will also be needed from the State of Hawaii DOH. During this process, the applicability of preventive measures, such as the use of silt curtains, will be discussed.

Toxicity is evaluated in Section 4.4.5.2. Jeopardy to protected species or adverse effects to habitat of concern (coral reefs) is thoroughly explored in the DEIS, Sections 4.4.1 and 4.4.3. The final outfall alignment and construction methods will be selected to ensure that impacts on the marine environment will be minimized. Mapping of the benthic communities along the outfall alignment will be performed. No marine sanctuaries will be affected by the proposed action.

Revision to the DEIS: The FEIS will discuss how the final outfall alignment and construction methods will minimize impacts to the marine environment. A figure mapping the benthic communities along the outfall alignment will also be included in the FEIS.

OUTFALL PIPE CONSTRUCTION

Comment: EPA recommends that the FEIS state that additional NEPA documentation will apply, once final design plans are finished and proper consultation with the Corps has been completed. Additional or supplemental NEPA documents should be tiered off the current EIS (40 CFR 1508.28(b)).

Response: Additional NEPA documentation will only be required if the selected alternative, including outfall alignment, is not properly evaluated. The final design concepts are developed within the context of this DEIS process. If the chosen alignment differs from the range of alternatives presented in the DEIS, a revised DEIS or a supplemental draft environmental impact statement will be published. If it does not differ, the FEIS will provide additional details (developed as part of the design and EIS processes) regarding the construction methods to be used for each section of the alignment.

Revision to the DEIS: Details regarding the construction methods to be used will be added to Chapter 2 of the FEIS.

ENVIRONMENTAL CONSEQUENCES AND MITIGATIONS/MONITORING

Construction Impacts

Comment: We recommend that the Navy use a more scientific approach to describe potential noise or other physical construction-related impacts to marine life, in particular the endangered green sea turtle. We are concerned about possible noise and vibration impacts from spudding and pile-driving to marine life.

Response: Noise generated from construction in the water has not been found to have significant effects on marine life, based on prior construction projects in Hawaii. As such, noise in the marine environment was not evaluated in detail. (References are cited in Appendix IX).

Response to the DEIS: None.

Comment: The FEIS should describe some of the other best management practices (BMP) to reduce construction-related impacts to reef-related biota. We are particularly concerned about potential fuel oil or hydraulic fluid spills related to construction activities.

Response: BMP to minimize potential pollution from construction equipment will be added to the FEIS. These BMP will include the use of silt curtains in shallow and protected waters, and frequent inspection and preventive maintenance of operating equipment to reduce potential for release of hydraulic fluids, lubricants, and fuel into the water from mechanical malfunction. All mobile equipment servicing will be performed out of the water (other than equipment installed aboard vessels or in case of emergency).

Revision to the DEIS: Section 4.4.1.4 will be revised to include the BMPs mentioned above.

Comment: The document should also describe any anticipated impacts and mitigation plans associated with storm events. Depending on construction method chosen, turbidity plumes in

deeper waters may be unavoidable, and appear to be sizable, especially the "Rock Zone," as shown on Figure 4.4-3. The Navy should amplify its description of potential negative impacts to marine biota from resulting turbidity in this zone. We are also concerned about the turbidity plume affecting the reef zone during storm events, or other unusual current conditions that could move the plume shoreward.

Response: The weather will be monitored and all equipment secured if a storm is anticipated. Response of marine organisms to intermittent turbidity from construction is documented in Appendix IX. Significant negative impacts are not anticipated, based on project specific analysis and historical evidence from other projects in Hawaii.

Assuming that the term "storm event" means periodic episodes of atypically higher winds and large waves, such storm waves result in substantially more turbulence and mixing in the water column than during non-storm periods. Hence, the increased turbulence flushes particulate material from the reef area, resulting in subsequently decreased turbidity. It has been well documented that the primary environmental factor affecting Hawaiian reef community structure is physical impact (concussive force) associated with storm waves, rather than turbidity. In fact, some well-established coral communities in Hawaii flourish in areas of continually elevated turbidity. On the other hand, if the term "storm event" is interpreted to mean high rainfall and subsequent runoff of terrigenous material, then the effects to the reef would be approximately the same with or without the construction, since the project will not affect erosion and runoff.

Revision to the DEIS: The FEIS will include requirements to monitor weather and secure the equipment if a storm is anticipated.

Operational Impacts

Comment: The DEIS states (page 4-30) that "…relocation of this nutrient source is not expected to cause negative environmental impacts." However, it does not say why. Because the proposed new pipe and diffuser are in a different physical location and different marine environment, it may be premature to conclude that significant impacts to the marine life, in general, could not occur from the new operations. The FEIS should justify the Navy's assertion that the discharge to open coastal waters (class A) would not have significant impacts to marine life.

Response: The assertion that relocating the outfall and associated nutrient source (effluent discharge) will have no significant negative effect on marine life is based upon observations at existing outfalls, including the outfall at Fort Kamehameha (see Appendix IX). Given the open and nutrient-poor receiving waters, ample mixing and dilution volume, and the quality of effluent being discharged, no mechanism for significant harm to the marine environment (in these specific conditions) has been observed. It is worth noting that the nutrient loading discharged by the outfall at Fort Kamehameha is one-third or less of the nutrient loading discharged naturally from the Pearl Harbor entrance channel at the same location, and hence, does not comprise the dominant source of nutrients in the area of potential effect. The natural discharge was considered in evaluating cumulative effects. The outfall relocation will enable greater dilution volume for the outfall discharge component, constituting a favorable change from the existing condition, which has had no significant effect on adjacent marine communities.

Revision to the DEIS: None.

Comment: The FEIS should also provide discussion of any expected thermal-related impacts (what is the difference between the effluent temperature and ocean temperatures and would there be any negative impact to marine life?), and impacts associated with discharge of brackish waters into open coastal waters.

Response: The mixing of the effluent discharge with ambient water is so rapid that the region of mixing is small. Thus, only a small portion of the water column has salinity and temperature characteristics that differ substantially from ambient conditions. Because the effluent plume will be generally warmer and less saline than the receiving water, the plume will rise following discharge. Based on the observation of existing outfalls, such rising plumes have virtually no contact with the benthic surface.

Revision to the DEIS: Chapter 4 will be revised to include this information.

Comment: The Navy should provide additional information on any anticipated environmental impacts from storm conditions or other unusual conditions not addressed by the model.

Response: With regard to storm or non-typical conditions, these are not relevant to plume behavior modeling because they are intermittent and have a relatively low frequency of occurrence. Two prevailing sets of oceanographic conditions were modeled, one each for the summer and winter, which included the dominant effects of currents and temperature stratification under the two prevailing climatic conditions.

Revision to the DEIS: None.

Monitoring

Comment: The FEIS should include monitoring provisions designed to ensure that all recommended mitigation and BMP are complied with. Furthermore, the role of various agencies in monitoring oversight of discharge permit conditions should be discussed. The Navy should discuss provisions for long-term monitoring of the effected environment within the ZOM, and larger area of the projected effluent plume.

Response: Monitoring requirements will be developed in cooperation with the DOH, Clean Water Branch during the discharge permit process of HAR Chapter 11-55.

Revision to the DEIS: This information will be included in the FEIS.

CUMULATIVE IMPACTS

Comment: The FEIS should include additional baseline material, as previously indicated in our comments entitled, Affected Environmental - Existing Environmental Degradation. We suggest that data may be available which describe and summarize the status of the affected environment and recommend that the data be presented in an effective format in the FEIS.

Response: The "affected environment" has been evaluated in the DEIS and found to be:

a. The benthic substrate which is directly impacted by construction activity:

b. The water column and bottom communities exposed to silt generated by construction activities; and

c. The water column and bottom marine communities affected by effluent discharged at the diffuser.

No cumulative impacts were identified for the areas directly impacted by construction activities. Bottom marine communities in the pipeline corridor have been stable over time and are common to Hawaii. In fact, they are similar to those bottom marine communities found in other such locations in Leeward Oahu. There are no indications that unique and significant external factors are affecting the area that would cumulatively interact with the proposed action. The directly impacted construction corridor is a small fraction of the reef flat in the vicinity and will naturally recover over time, as has occurred with other such projects. Interaction of the proposed discharge with other outfalls in Mamala Bay were evaluated by far-field modeling and found not to be significant.

Revision to the DEIS: None.

Comment: The Navy should expand and enhance its analysis and treatment of cumulative impacts in the FEIS. The DEIS (page 4-24) indicates that "the existing outfall accounts for only nine percent of the total estimated water input and about one percent of the estimated solids input into the estuary." Cumulative impacts can results from individually minor but collectively significant actions taking place over a period of time (40 CFR 1508.7).

Response: The probable range and extent of sedimentation from construction activities is depicted in Figure 4.4-3. Only the reef flat was found to be influenced by seasonally affected, wind-driven water movement. The rest of the area is subject to tidal variation. Water samples (see Appendix VIII, Table 8), obtained over several testing periods for waters near and surrounding the project area, indicate that the geometric mean for turbidity is somewhat elevated in the inner Pearl Harbor transect, probably due to the influence of the estuarine discharge, including the existing outfall. Adjacent areas both up and down the shoreline, and offshore areas (e.g., up current and down) were similar and generally within standards. There is no reason to believe cumulative influences exist that will significantly interact with temporary sedimentation in the water column caused by project construction. No such cumulative influences were identified in scoping for the area of potential effect, and objective water quality data do not indicate the presence of such stresses.

Revision to the DEIS: None.

Comment: The DEIS notes that at the point of maximum overlap of effluent plumes, cumulative nutrient levels would be increased up to 49 percent above the ambient conditions but would still meet DOH water quality standards. The conclusion reached is that "...no significant cumulative impacts on water quality will results from the proposed action." It is erroneous to conclude that, just because water quality standards will be met, no significant cumulative impacts will occur. The Navy should describe the expected cumulative

environmental impacts, in particular to the reef environment, from this cumulative nutrient loading.

Response: Far-field modeling was conducted using modeling input developed for the Mamala Bay Study. This modeling indicated a worst case combined loading occurred where dilution isopleths of 5000:1 from Fort Kamehameha intersected with the 10,000:1 isopleth from Sand Island. At this worst case location, the worst case nutrient, nitrite + nitrate nitrogen, is elevated 49% above background (as measured) under worst case conditions (winter). The total value of this worst case scenario is 1.54 mg of nitrite + nitrate nitrogen/l, or about 30 percent of the geometric mean standard, and one tenth of the not-to-exceed 10% of the time standard. Hawaii water quality standards are established to be protective of the beneficial uses of waters for each classification. For class A water, these values include "protection and propagation of fish, shellfish, and wildlife..." (HAR Chapter 11-54-03). This worst case cumulative effect occurs four to five kilometers off-shore in deep, nutrient-poor, open waters, and assumes only dilution, ignoring the effects of biological uptake that would further reduce nutrient concentrations. There is no evidence to indicate any cumulative effect on the marine environment will occur from this condition.

Revision to the DEIS: None.

Comment: EPA believes that further evidence justifying Navy's conclusion that the long term discharge of the treated effluent will not be toxic to fish or other aquatic life or create health hazards for the area's recreational users (page 4-49) is necessary.

Response: The result of whole effluent toxicity testing is summarized in Section 4.4.5. In addition to the material presented in the DEIS, an evaluation of the accumulation of certain potentially toxic chemicals in sediments surrounding the existing outfall was conducted using samples obtained as part of this study (MCON Project P-497, *Oceanographic Study for Outfall Extension for Wastewater Treatment Plant at Fort Kamehameha*, Volume I Report, SSFM Engineers, October 1996). Sediment samples were obtained from two locations in the vicinity of the existing outfall, one location immediately adjacent to the outfall and one location about 2,000 feet toward the ocean in the channel bottom. Samples from these two locations were compared with each other and against background averages for Pearl Harbor, obtained from literature of prior studies. Selected analytes included arsenic and heavy metals. For all analytes, the measured parameters at the adjacent and distant sampling locations were essentially the same, with no reflection of logarithmic decline in deposition as would be expected to occur if the outfall were the source of these contaminants. When compared with average values for the same constituents throughout the Pearl Harbor Entrance Channel, taken over a period of years, most constituents near the outfall were essentially the same or lower than these historic averages, with only copper being slightly higher. In summary, the physical sampling yielded no evidence that toxic constituents in the effluent are being deposited in the ocean environment.

Revision to the DEIS: This information will be added to the FEIS.

Comment: In terms of "short term use of the environment v.s. long term productivity," the DEIS states (page 4-68): "The ocean's capacity for proper disposal of treated wastewater effluent is a renewable resource. Use of the ocean for disposal of effluent from the WWTP at Fort Kamehameha will have no long-term detrimental effects on the ocean environment or

its productivity." We suggest that the cumulative effluent disposal, dredging-related activities, and anthropogenic surface water point and non-point source discharge have significantly affected the near shore Mamala Bay environment. As an example, nutrient loading can impact the marine ecosystem and may cause algae blooms, changes in dominant species, and other, perhaps poorly understood, impacts as a "chain" of events. Potential cumulative loading of toxics from the Fort Kamehameha WWTP and other facilities could have a detrimental effect on the ocean environment. In conclusion, within a framework of sound methodology and scientific integrity, the FEIS should contain a description of the existing negative cumulative impacts to the affected environment and a discussion of potential long-term cumulative impacts from the proposed project and other activities.

Response: There is no doubt that the shoreline environment of Mamala Bay has been highly altered from its natural state, and that water quality in nearshore waters has been affected by human activity in the coastal zone. The question is whether the proposed action, considered cumulatively with the effects of these other changes over time, will pose a significant impact. We have addressed these issues individually above, and have found no evidence that the proposed action, as properly designed, will interact with other factors in any way to cause significant impacts to the ocean environment. Where scoping issues or matters raised during investigation have indicated a reasonable possibility of cumulative effects, these potential effects have been evaluated, such as the far-field interaction with other discharges. Speculative impacts have not been analyzed, and are not required to be analyzed under CEQ regulations.

Revision to the DEIS: None.

ERRORS AND/OR OMISSIONS

Comment: The document should have an index, as required at 40 CFR 1502.10.

Response: Acknowledged.

Revision to the DEIS: An index will be provided as part of the FEIS.

Comment: The description of outfall alignment erroneously refers to Figure 1.2-2. It should refer to Figure 1.2-3.

Response: Acknowledged.

Revision to the DEIS: Figure references regarding alignment options in Section 2.3.3.2 will be changed from Figure 1.2-2 to Figure 1.2-3 ("Proposed Outfall Alignment and Diffuser Alternatives").

Comment: Regarding the reference to Figure 2.3-2 on page 4-27; this figure does not depict distribution of "bottom types."

Response: Acknowledged.

Revision to the DEIS: The reference in Section 4.4.1.3, regarding the distribution of bottom types along the proposed alignment, will be changed from Figure.2.3-2 to Figure 3.4-1 ("Bottom along Pipeline Route").

We trust these responses have adequately addressed your concerns.

Should you have any questions, please contact Mr. Gary Kasaoka (Code 231GK) at (808) 471-9338 or by facsimile transmission at (808) 474-5909.

Sincerely,

Melvin N. Kaku

MELVIN N. KAKU
Director
Environmental Planning Division

Copy to:
Belt Collins Hawaii
680 Ala Moana Boulevard, First Floor
Honolulu, HI 96813

DEPARTMENT OF THE AIR FORCE
PACIFIC AIR FORCES

6 JAN 1998

MEMORANDUM FOR Pacific Division
Naval Facilities Engineering Command
Attn: Mr Kasaoka (231GK)
Pearl Harbor, HI 96860-7300

FROM: HQ PACAF/CEV
25 E St Ste D306
Hickam AFB HI 96853-5412

SUBJECT: Draft Environmental Impact Statement for Proposed Outfall Replacement for Wastewater Treatment Plant at Fort Kamehameha

We completed our review of subject document and have no comments. Our point of contact is Capt Scott Bridgeman, HQ PACAF/CEVP, 449-2791.

James W. Kahler
JAMES W. KAHLER, Colonel, USAF
Chief, Environmental Quality Division
Directorate of The Civil Engineer

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
(MAKALAPA, HI)
PEARL HARBOR, HAWAII 96860-7300

5090P.1F3C
Ser 2317 2179
8 JUN 1998

From: Commander, Pacific Division, Naval Facilities Engineering Command
To: Commander, Pacific Air Forces (CEV)

Subj: DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS) FOR OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR

Ref: (a) PACAF/CEV memo of 6 Jan 98

1. This responds to reference (a) which states that the Pacific Air Forces has reviewed subject document and has no comments to offer. Your review of the DEIS is greatly appreciated.

2. Should you have any questions, please contact Mr. Gary Kasaoka (Code 231GK) at 471-9338 or by facsimile transmission at 474-5909.

Melvin N. Kaku
MELVIN N. KAKU
By direction

Copy to:
Belt Collins Hawaii
680 Ala Moana Boulevard, First Floor
Honolulu, HI 96813

BENJAMIN J. CAYETANO
GOVERNOR OF HAWAII

STATE OF HAWAII

DEPARTMENT OF LAND AND NATURAL RESOURCES

STATE HISTORIC PRESERVATION DIVISION
33 SOUTH KING STREET, 6TH FLOOR
HONOLULU, HAWAII 96813

MICHAEL D. WILSON, CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES

DEPUTIES
GILBERT COLOMA-AGARAN

AQUACULTURE DEVELOPMENT PROGRAM
AQUATIC RESOURCES
CONSERVATION AND RESOURCES ENFORCEMENT
CONVEYANCES
FORESTRY AND WILDLIFE
HISTORIC PRESERVATION DIVISION
LAND DIVISION
STATE PARKS
WATER AND LAND DEVELOPMENT

REF: HP-JEN

JAN -6 1998

LOG NO: 20599
DOC NO: 9712SC05

Mr. Stanley Y. Uehara, Acting Director
Environmental Planning Division
Department of the Navy, Pacific Division
Naval Facilities Engineering Command
Pearl Harbor, Hawaii 96860-7300

Dear Mr. Uehara:

SUBJECT: **National Historic Preservation Act, Section 106 Compliance - Review of a Draft Environmental Impact Statement (DEIS) for Proposed Outfall Replacement for Wastewater Treatment Plant at Fort Kamehameha**
Halawa, 'Ewa District, O'ahu TMK: 9-9-1

Thank you for the opportunity to review and comment on the draft Environmental Impact Statement (DEIS) prepared for the proposed outfall replacement for the Fort Kamehameha wastewater treatment plant at Fort Kamehameha, O'ahu. Our review is based on historic reports, maps, and aerial photographs maintained at the State Historic Preservation Division. In addition, Sara Collins and Elaine Jourdane of my staff made a brief visit of the general project area in November 1997, in the company of Hickam Air Force Base personnel. Finally, Ms. Annie Griffin of your office provide us with two draft archeological reports for informational purposes, to assist us in this review (*Preliminary Report. Phase IV: Archaeological Monitoring, Testing, and Emergency Data Recovery at Fort Kamehameha Wastewater Treatment Plant Pearl Harbor, Hawai'i.* 1996. Drolet; *Prefinal Report. Phase II Archaeological Subsurface Testing and Data Recovery, Wastewater Treatment Plant at Fort Kamehameha, Pearl Harbor, O'ahu, Hawai'i.* Vol. 1. 1997. Drolet et al.).

In general, we believe that the DEIS adequately discloses the nature and potential effects of the undertaking. The underwater portion of the proposed undertaking will be carried out within the existing channel, which has been dredged periodically over the decades; none of the WW II-era aircraft or shipwrecks are known to be in the vicinity of the proposed outfall. The construction parcels adjacent to the project site are either paved over or have undergone subsurface testing with no significant historic sites found. In view of these facts, we concur with the determination in the DEIS that the proposed undertaking will have "no effect" on significant historic sites.

Should you have any questions, please feel free to call Sara Collins at 587-0013.

Aloha,

Gilbert Coloma-Agaran
Michael D. Wilson, Chairperson and
State Historic Preservation Officer

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
(MAKALAPA, HI)
PEARL HARBOR, HAWAII 96860-7300

5090P.1F3C
Ser 231/2286
16 JUN 1998

Mr. Michael D. Wilson
State Historic Preservation Officer
Department of Land and Natural Resources
33 South King Street, Sixth Floor
Honolulu, HI 96813

Dear Mr. Wilson:

Subj: DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS) FOR OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR

Thank you for your letter of January 6, 1998, in which you acknowledged completing review of subject document. We are pleased that you consider that the DEIS adequately discloses the nature and potential effects of the proposed action and that you concur with the determination that the proposed action will have "no effect" on significant historic sites.

Should you have any questions, please contact Mr. Gary Kasaoka (Code 231GK) at 471-9338 or by facsimile transmission at 474-5909.

Sincerely,

Melvin N. Kaku
MELVIN N. KAKU
Director
Environmental Planning Division

Copy to:
Belt Collins Hawaii
680 Ala Moana Boulevard, First Floor
Honolulu, HI 96813

BEST INDUSTRIES USA, INC.
851 Nana Honua Street
Honolulu., Hawaii 96825-1074
Phone: 808-394-2323 Fax: 808-396-3900

January 7, 1998

Commander
Pacific Division, Naval Facilities Engineering Command

Attention: Mr. Gary Kasaoka (Code 231)

Subject: Draft Environmental Impact Statement for Outfall Replacement at the Wastewater Treatment Plant at Fort Kamehameha, Navy Public Works Center, Pearl Harbor, Hawaii

Gentlemen:

Thank you for the opportunity to provide comments on the subject project. From the perspective of a private citizen as well as prospective third-party vendor, the subject project addresses only the outfall from the existing wastewater treatment facility. A replacement outfall will transmit treated wastewater for ocean disposal, resulting in the loss through discharge of valuable fresh water. This system does not allow for possible re-use of treated wastewater.

Furthermore, the potential for direct contaminated wastewater discharge is significant under the current wastewater treatment process. It is our recommendation that the total wastewater system be examined for alternatives which may provide lower operating costs while allowing for re-use of treated wastewater.

As was presented at the informational briefing, our company, Best Industries USA, Inc. has a product which may be a viable and cost effective alternative. The Johkasou system is a compact On-site Wastewater Treatment tank which treats wastewater to a secondary quality effluent. With proper manufacturing, construction, installation, and maintenance, the Johkasou system will help us to maintain a healthy living environment and to preserve the water quality of public areas such as seas, lakes and rivers.

Enclosed please find a brochure which provides additional information about the Johkasou On-site Wastewater Treatment tank. We feel that the installation of the Johkasou tanks will meet the wastewater treatment and water re-use requirements at Fort Kamehameha. We also believe that the potential applications within the military for this technology is significant. We would welcome the opportunity to further discuss this with you or other members of PacDiv.

Should you have any questions please contact me at 394-2323.

Sincerely,

WHAT IS JOHKASOU?

There are many districts in Japan where public sewage systems are not available. In order to use flush toilets in these districts, it is necessary to install wastewater purifying facilities called "johkasous" to treat the wastewater from toilets independently or in combination with miscellaneous domestic wastewater (known as "gray water") from baths, kitchens, laundries and so on.

Everywhere in Japan "johkasou systems" are commonly installed and used for this purpose. The meaning of this system comes from the Japanese words, "johka" literally meaning purification, and "sou" meaning tank.

Johkasou systems, uniquely developed in Japan, are used throughout the country. With proper manufacturing, construction, installation, and maintenance, Johkasou systems help us to maintain a healthy living environment and to preserve the water quality of public areas such as seas, lakes, and rivers. The recently developed compact Johkasou systems, which treats the wastewater consisting of both night soil and gray water, can be installed in individual homes to discharge the effluent of less than 20 mg/l, in terms of BOD, which is comparable to the final tertiary treatment of public sewage systems.

Johkasou-based wastewater management systems may prove useful in other countries or districts where sewage systems are not available. ◆

BENEFITS
Johkasou System

- ✔ Helps to reduce county expenditures for maintaining central sewer system, which keeps increasing.
- ✔ Helps county budgets from developing new costly central sewer systems
- ✔ Creates more jobs: manufacturing, engineering, scientific, maintenance, installation
- ✔ System can be manufactured at an affordable cost
- ✔ Shortens construction time for developer, saves interest cost and development cost
- ✔ System has no moving parts
- ✔ Maintenance is low cost and less time
- ✔ Wastewater collection and Johkasou installation are not affected by topographic condition at site
- ✔ Over 30 years of proven research and development technology in Japan

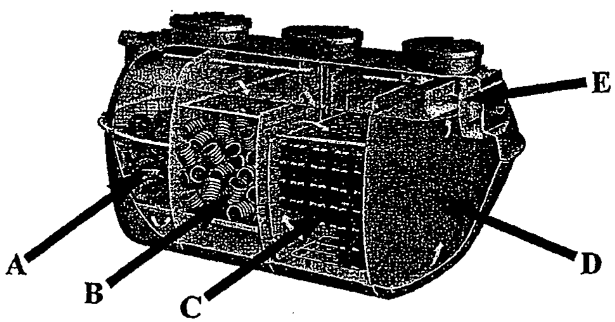
Model UCZ5~10 household sewage disposal tank system consists of five chambers in a single tank. The five chambers are:

A & B. ANAEROBIC FILTRATION CHAMBERS
Chamber A & B are packed with filtration material. The fundamental nutritional material in the wastewater will be decomposed by the anaerobic bacteria which is formed on the surface of the filter material.

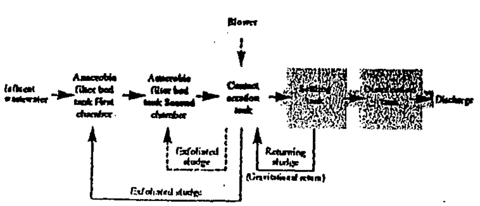
C. CONTACT AERATION CHAMBER
C Chamber is filled with the contact materials. The aeration pipes are located on the bottom of the chambers. Wastewater from the Anaerobic Filtration Chambers (Chambers A & B) goes into the Aeration Chamber. The fundamental nutritional material of the wastewater from the Anaerobic Filtration Chamber will be eliminated by oxidation when the wastewater comes in contact with the biotic membrane which is formed on the surface of the contact material. The aeration pipe is installed under the contact material and backwashes the contact material. The sludge overflow will then be returned naturally to the Anaerobic Filtration Chamber or the Settling Separation Chamber (D Chamber.)

D. SETTLING SEPARATION CHAMBER
The small quantities of plankton in the Anaerobic mixed liquid from the Anaerobic Filtration Tank and sludge overflow from the biotic membrane will be separated as it rises with the clear liquid at the top in the Settling Separation Chamber. It will then return naturally to the Contact Aeration Chamber.

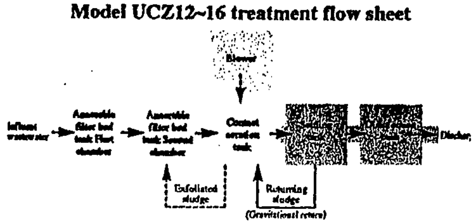
E. DISINFECTION CHAMBER
The clear liquid at the top from the Settling Separation Chamber will contact with the disinfectant material through the Overflow installed at the entrance of the Disinfection Tank. It will then enter into the Disinfection Tank for the chlorine sterilization process, and then be discharged as effluent.



Model UCZ5~10 treatment flow sheet



Model UCZ12~16 treatment flow sheet



ENVIRONMENTAL BENEFITS

- ✔ Environmentally better for treating wastewater to be used to recharge ground water or for irrigation
- ✔ Eliminates nitrate and phosphorous from wastewater - it does not contaminate groundwater, lakes and oceans
- ✔ Provides permanent solution, where system does not exist, to reduce county expenditures for maintaining central sewer system, which keeps increasing
- ✔ Helps to conserve water supply by recycling wastewater for irrigation and helps to recharge groundwater
- ✔ A more permanent solution than septic tank or cesspool
- ✔ Does not contaminate or pollute any drinking water or potential drinking water supply or any waters of any beaches, shores, ponds, lakes, streams and groundwater
- ✔ Is not a hazard to public health safety or welfare
- ✔ Will not create foul or noxious odors
- ✔ No leach field needed, only a small pit
- ✔ Causes no noise problems
- ✔ Creates a pleasant, hygienic living environment

BENEFITS FOR HAWAII

- ✓ First State in the USA to use and develop the Johkasou system
- ✓ First State in the USA to develop and research ways to clean our water sources, groundwater, lakes and oceans
- ✓ First to develop a high technology center for the entire USA. Will work with the University of Hawaii for information and support.
- ✓ Help UH Manoa and UH Hilo to receive grants for further development with wastewater and water purification
- ✓ First state to help the military sewer system to become more cost and manpower efficient
- ✓ Encourage other Japan companies in wastewater development to come to Hawaii
- ✓ Construction or development of areas that are at its maximum waste capacity to its central sewer system
- ✓ We will be developing a footprint concept of the technology to present to the rest of the US cities. Therefore, Hawaii will have other US cities and states looking to us for information and visiting the islands to learn from our experience. And they will also visit Hawaii as tourists, which will help our economy.

BEST INDUSTRIES USA, INC.

BEST INDUSTRIES USA, INC., a Hawaii corporation, is a joint venture between Environmental Waste Management Systems, Inc. of Honolulu, Hawaii and Best Industries, Inc. of Osaka, Japan. Best Industries USA, Inc. will be serving the entire United States.

ENVIRONMENTAL WASTE MANAGEMENT SYSTEMS (EWMS) is a company which is dedicated to the research and development of a comprehensive water treatment system to include water supply systems, ultra purifiers, and wastewater systems for domestic and industrial waste. EWMS is a Hawaii Corporation, Harold K. Nagato is the President of this company. Mr. Nagato is also the President of Area Builders, Ltd.

Best Industries Inc., is a Japan Corporation. Dr. Masao Kondo is the President of this Company and is a pioneer as a manufacturer of a comprehensive water treatment system and has endeavored to develop an innovative technology for water treatment. Best Industries Inc. works to develop the ultimate wastewater treatment system by employing both technological innovations and comprehensive know how.

By the joining of these two companies EWMS and Best Industries, Inc., being "a bold pioneer spirit" will be born in the USA and in so doing, we hope to achieve our corporate mission of protecting the earth's precious environment.

BEST INDUSTRIES, INC.

"A BOLD PIONEER SPIRIT" are the words used to sum up the philosophy behind the array of creative products and high-quality systems developed by Best Industries Inc. since its beginning in 1968 - almost thirty years ago!

- A TECHNICAL RESEARCH INSTITUTE
- THREE FACTORIES
- 40 BRANCH SALES OFFICES
- 17 DISTRIBUTION CENTERS

We will continue to "do our best" as we develop comprehensive water treatment systems, including water supply systems, ultra purifiers and other products, as well as an even more efficient waste water treatment systems for treating both domestic and industrial wastewater.

JOHKASOU VS. OTHER SYSTEMS

	Cost Per Home	Life Expectancy	Maintenance Per Year	Good for Environment	Recycles Water to R1 Quality	Water Treatment
Central	$60,000 - $80,000	20 - 25 years	$420.00[2]	No	No[7]	Primary[7]
Cesspool	$ 9,000 - $16,000[1]	5 - 10 years	$100 - $800[2]	No	No	None
Septic	$ 6,000 - $12,000[1]	5 - 10 years	$100 - $800[2]	No	No	None
Johkasou	$12,000 - $16,000[3]	25 + years[4]	$300.00[3]	Yes[5]	Yes[6]	R1[6]

1. Waimanalo Wastewater Facilities Plan, Chapter 7 (Hawaii Pacific Engineers, Inc.)
2. City & County of Honolulu, Public Works Infrastructure, Chapter 14.
3. Best Industries, Hawaii, Inc.
4. Best Industries, Inc.
5. Proposal from Kurashi-no-Techno, Professor Junko Nakanishi at Tokyo University.
6. Project - Development of a Residential Wastewater Treatment System to Produce R-1 Quality Reclaimed Water, University of Hawaii, Professor Roger Babcock, 1997.
7. City & County of Honolulu, Sand Island Treatment Facility.

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
(MAKALAPA, HI)
PEARL HARBOR, HAWAII 96860-7300

5090P.1F3C
Ser 231/ 1680
01 MAY 1998

Mr. Harold K. Nagato
Best Industries USA, Inc.
851 Nana Honua Street
Honolulu, HI 96825-1074

Dear Mr. Nagato:

Subj: DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS) FOR OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT (WWTP) AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR, HAWAII

Thank you for your written comments of January 7, 1998, on the DEIS for the above referenced action. Our response to your comments are as follows:

Comment: From the perspective of a private citizen as well as prospective third-party vendor, the subject project addresses only the outfall from the existing wastewater treatment facility. A replacement outfall will transmit treated wastewater for ocean disposal, resulting in the loss through discharge of valuable fresh water. This system does not allow for possible re-use of treated wastewater.

Response: As discussed in Section 2.5.2.3 of the DEIS, constructing the outfall does not preclude future effluent reuse. Should a water reclamation or desalination facility be built at the WWTP in the future, the proposed outfall will provide a means for disposing of the brine by-product and any excess or off-specification wastewater without having to first construct a new disposal facility for the new waste stream.

Revision to the DEIS: None.

Comment: The potential for direct contaminated wastewater discharge is significant under the current wastewater treatment process. It is our recommendation that the total wastewater system be examined for alternatives which may provide lower operating costs while allowing for re-use of treated wastewater.

Response: In Section 1.4, we stated the capacity of the WWTP at Fort Kamehameha was recently expanded to include secondary treatment with anoxic basins to improve sludge settling characteristics, sand filtration to improve suspended solids removal, and ultraviolet disinfection to improve pathogen destruction prior to effluent discharge. Cost-effective effluent reuse is a Navy goal. As discussed in Section 2.5.1.1, "best-case" assumptions were incorporated into the reuse alternative.

Revision to the DEIS: None.

Subj: DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS) FOR OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT (WWTP) AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR, HAWAII

Comment: Best Industries USA, Inc. has a product which may be a viable and cost effective alternative. The Johkasou system is a compact On-site Wastewater Treatment tank which treats wastewater to a secondary quality effluent. With proper manufacturing, construction, installation, and maintenance, the Johkasou system will help us maintain a healthy living environment and to preserve the water quality of public areas such as seas, lakes and rivers.

Response: The Johkasou system appears to have merit for areas that are not served by existing collection systems, and where individual wastewater systems are permitted by State and local authorities. Such systems are generally not permitted where existing collection systems are available, as is the case for the WWTP at Fort Kamehameha service area.

Revision to the DEIS: None.

Due to discovery of a soft-soil condition along the original outfall alignment proposed in the DEIS, a new alignment around the soft spot is being designed. A supplemental draft environmental impact statement (SDEIS) will be issued in the fall of this year to cover the new engineering challenge. All recipients of the original DEIS will remain on the distribution list to receive the SDEIS and other subsequent documents related to the EIS

Should you have any questions, please contact Mr. Gary Kasaoka (Code 231GK) at 471-9338 or by facsimile transmission at 474-5909.

Sincerely,

Melvin N. Kaku
MELVIN N. KAKU
Director
Environmental Planning Division

Copy to:
Belt Collins Hawaii
680 Ala Moana Boulevard, 1st Floor
Honolulu, HI 96813

Stephen T. Kubota
Ahupua'a Action Alliance
44-281 Mikiola Dr.
Kaneohe, HI 96744

To: Mr. Gary Kasaoka (Code 231GK)
Pacific Division, Naval Facilities Engineering Command
Pearl Harbor, HI 96860-7300
By Fax Transmission: 474-5909

Subject: Ft. Kam WWTP DEIS
Ref: Public Hearing on December 17, 1997, Radford High School Library

Preface

The following written comments summarize my oral comments presented at the referenced public hearing and expand upon the dialogue that emerged at the meeting. Please refer to the taped transcript of the discussion. Appreciation is expressed to the staff of Belt, Collins in providing a written summary of my oral comments.

Numerical citations, i.e (2-2) refer to page numbers in the DEIS. Citations referring to the Water Commission's Proposed Findings of Fact, Conclusions of Law, and Decision and Order, dated July 15, 1997 are indicated as (CWRM, [page no.]). The Commission issued its final order on December 24, 1997 but the author has not had an opportunity to reconfirm the references. However since the references cited are exclusively from the Findings of Fact section of the document no substantive changes are anticipated.

Concerns

1. Upgrading of the existing facility.
   a. The EPA letter to Navy Public Works Center dated January 24, 1997 stated: "Compliance could be assured in two principle ways. First, flows could be discharged through a new deep ocean outfall into Class A open coastal marine waters which are not "water quality limited" for nutrients. Second, concentrations could be lowered through additional treatment steps to remove nutrients."
   b. This option should be fully explored as suggested by the EPA letter and included in the comparison tables along with the other options. The DEIS states: "To reduce pollutant loading to these waters, additional costly treatment, which is not practical, would be necessary at the WWTP" (2-2). This simple statement does not permit adequate comparison to the other options especially as it relates to the reuse option.
   c. The WWTP was upgraded from 7 mgd capacity (1992 levels) to 13 mgd. (1-9). The only references to "costly additional treatment" are all related to the desalination of R-1 effluent for irrigation of terrestrial landscaping (2-42).
   d. What are the costs related to "additional treatment steps" to permit discharges through the existing outfall?

Comments to DEIS for Ft. Kam WWTP Outfall Replacement

2. Water as a resource.
   a. The DEIS does to evaluate water as a resource. The Navy was a party in the Waiahole Ditch Contested Case Hearing, represented by Mr. Paul Sullivan, Esq. of the Naval Facilities Engineering Command, and is aware that extensive testimony was received that water demand will exceed the existing yield. In its press release of July 15, 1997 announcing its proposed decision on the Waiahole Ditch, the Commission stated: "The evidence presented in the case illustrated that the demand for water by the year 2020 for projected growth on O'ahu exceeds the remaining ground water sources available." This statement does not include the increased demand on potable water for future development within the Pearl Harbor/Hickam complex. (see CWRM, 66-71)
   b. The potable water supply to the service area is 22 to 34 mgd from the Pearl Harbor System (Waiawa, Red Hill and Halawa and 2.5 to 3.5 mgd from the Barbers Point System for a combined total of 24.5 to 37.5 mgd. (CWRM, 67)
   c. The Navy's interest in the Waiahole Ditch case centered on irrigation for agricultural uses within the Blast Zone. Reclaimed water from the Ft. Kam WWTP could supply that need. The Water Commission stated: "The policy of the Commission is to encourage the utilization of lower quality water like reclaimed or brackish water for irrigation purposes, replacing the use of high quality ground water." (Press release, July 15, 1997.)
   d. The 30 year cost analysis for the reuse option is overstated if the projected demand on ground water sources is exceeded in 22 years.
3. Integrated Water Resource Management.
   a. The Water Commission further stated: "an integrated water resource plan must be developed to address how we will meet water demand given our dwindling supply." (Press release, July 15, 1997.)
   b. The DEIS does not consider an integrated approach to the problem. During the scoping hearing, the Alliance urged that full consideration be given to the fact that the Pearl Harbor/Hickam complex draws its potable water from mauka sources that would normally discharge through the natural ecosystems surrounding the estuary.
   c. The reuse option should be evaluated to consider restoration of the larger landscape and to address environmental justice concerns related to the displacement of traditional agricultural and aquculture production that historically existed in and around Pearl Harbor.
4. Environmental Justice, EO 12898
   a. The DEIS only addresses environmental justice concerns in the area of the proposed outfall and acknowledges a minimal impact because of limited public access. At the scoping meeting, the Alliance recommended that environmental justice impacts be assessed to include those resulting from the the withdrawal of groundwater that formerly flowed to the estuary.
   b. The DEIS continues a "Gated Community" image for the Navy. The Navy obtains its potable water from outside the Pearl Harbor/Hickam complex, processes wastewater generated within the complex and proposes to dispose of the effluent outside of the complex in the publicly owned Class A open

waters of the State. The effluent reuse option focuses only on federal property, i.e. golf courses and airport facilities. At the scoping meeting the Alliance urged that the Navy to consider the reuse option to support the civilian population displaced by RIF's and the closure of sugar operations in the surrounding community.

c. Annexation Centennial Observance. The Navy's acquisition of Fort Kamehameha and Pearl Harbor is directly linked to the Joint Resolution of Annexation by which the Republic of Hawaii ceded to the United States all public lands including "ports, harbors, military equipment and all other public property of every kind and description. . ." On August 12, 1998 the People of Hawaii will be observing the Centennial of the Annexation which the Congress has described as resulting from an "illegal act of war" which overthrew the Constitutional Monarchy of the Kingdom of Hawaii. (US Apology, PL 103-150). While it is beyond the scope of this DEIS to discuss these isssues in any depth, it is appropriate to expect that the preparers of the document to acknowledge the historical reality and display sensitivity to the cultural and social impacts of the proposed action and alternatives.

Reuse Option

1. The Reuse Option should be considered the preferred alternative
   a. DOH Guidelines for the Treatment and Use of Reclaimed Water, November 22, 1993.
      - These Guidelines are referred to several times restraints on the Reuse Option. In testimony before the Water Commission in the Waiahole Ditch CCH, Dr. Bruce Anderson states that these guidelines are "not set rules, do not have the force of law, and do not actually prohibit any uses of reclaimed water." (CWRM, 92)
   b. EPA/City Consent Decree on Wastewater Reclamation and Reuse.
      - The City has agreed to produce 10 mgd of reclaimed water by the year 2000.
2. Cost Analysis for the Reuse Option is overstated
   a. The DEIS uses an estimated unit cost of $0.96/cm for effluent reuse compared to $0.30/cm for current BWS nonpotable source. (2-49) It was difficult to convert these unit costs from cm (cubic meter) to kg (thousands of gallons) to compare them to other BWS rates. The BWS rate for non-potable water converts to $1.135 per kg. This compares to agricultural rates for potable water (under 250,000 gals per day) which run from $1.77 per kg up to 13,000 gallons and drops to $.75 per kg thereafter. (CWRM, 105) The use of BWS agricultural rates for potable water is a more appropriate comparison considering the conversion of brackish wells to agricultural uses.
   b. Cost analysis is based on comparisons to current costs of non-potable water. It should be based on projected costs of potable water. Water Commission finding that Oahu will exceed its developable yield by the year 2020 (within the 30 year cost analysis period).
   c. Reuse option is based on desalination cost of produce R-1 effluent for land-based agriculture and the 300 ppm chloride levels for reuse over potable

aquifers. Lower desalination costs (higher chloride levels) are acceptable for reuse below the No-Pass Line (H-1 freeway) and for aquaculture, coastal wetlands and coastal strand plants.

3. Coastal Aquaculture/Agriculture
   a. From ancient times, the Pearl Harbor complex and its surrounding environment was a rich source of food for the native population. Fishing, gathering, saltwater and freshwater fishponds and taro irrigation systems were prolific in the area. Remnant of these systems are still in evidence.
   b. Brackish water is suitable not only for edible aquaculture/agricultural products but can also be used to support commercial production of ornamental plants, native species and other coastal strand biota to create a vegetated buffer around the WQLS to retard erosion, sedimentation and nutrient loading. Commercial aquaculture/agriculture will increase nutrient uptake and removal with positive benefits to the receiving waters while providing a source of revenue to off-set the additional costs of treatment for reuse.
4. Reuse sites:
   a. New housing developments on Ford Island as well as the proposed USS Missouri memorial are ideal sites for installation of dual transmission infrasturcture. Reclaimed water an be used during construction, for maintenance, landscaping, fire control, toilet flushing, etc.
   b. Agriculture/aquaculture uses within the Blast Zone and the Waipio peninsula should explore revenue generating crops to off-set the additional costs of a delivery system. For example: UH-WRRC conducted a study entitled "Irrigation of California Grass with Domestic Sewage Effluent." "The study concluded that irrigation of California grass is an effective means of removing nitrogen from domestic sewage effluent and produces a crop suitable for feeding dairy cattle. Approximately 69% of the nitrogen was removed by plant uptake." (CWRM, p.98)
   c. Brine disposal will not affect the potable aquifer since potential disposal sites are located below the H-1 Freeway (the Board of Water Supply's No-Pass Line). The Naval/FAA Reservation in Pu'uloa is located in an area that was historically a salt pond/mill and should be evaluated for brine disposal.

Recommendations

1. Outfall Replacement Option
   a. Use the Outfall Replacement option as the cost-effective "fall-back" alternative.
   b. The costs related to the Outfall replacement can be used as a benchmark to "negotiate" for additional sources of funding to implement other options as discussed below.
2. Plant Upgrade Option
   a. Develop a detailed analysis of the Plant Upgrade option to allow better comparison with the other alternatives, especially its relationship to the re-use option.
   b. The costs for plant upgrade may be a function of improvements to the supply-side input to the system such as improvements to the industrial

treatment facility, efficiency to the delivery transmission system and user education related to water conservation, household chemicals and alternative disposal of hazardous materials. These functions are appropriately part of an integrated water resource mangement strategy coupled with community based watershed management. The Water Commission stressed that "there must be an increased emphasis on water conservation, water reclamation and reuse, and improvements to delivery system efficiency." (Press release, July 15, 1997.)

3. Reuse Option

a. Re-examine the Reuse Option in light of the Water Commission's decision in the Waiahole Ditch Contested Case Hearings, especially those findings of fact related to water as a resource (cost analysis) and the potential for aquaculture/agriculture reuse below the H-1 Freeway and projected development within the Pearl Harbor complex, especially Ford Island and the USS Missouri memorial.

4. Environmental Credit Option

a. Develop an expanded analysis of the total water/pollution budget for the entire WQLS of the Pearl Harbor estuary.

b. Seek EPA support for using an "environmental credit" approach to evaluating the impact of the the current outfall if improvement can be made to the overall Pearl Harbor WQLS.

c. NPDES Permit extension. If the Navy were to develop a long-term strategy to develop an integrated water resource management plan that included supply-side conservation, wastewater reclamation and reuse, dual transmission systems and community based watershed management, the EPA may be willing to consider an extension on the permit conditioned upon implementation of this strategy. The extension period would be used to secure interagency commitments, public participation and additional funding sources.

5. Community Based Watershed Management

a. Explore the feasibility of establishing a joint DOD/Civilian Community Based Watershed Management Plan for the Pearl Harbor Estuary. There are currently three active projects that can serve as prototype models:

b. The 1997 Kaneohe Bay Task Force presented its preliminary report at a public hearing held on January 7, 1998 evaluating the status and effectivenes of the Kaneohe Bay Regional Council in facilitating implementation of the Kaneohe Bay Master Plan. The Executive Summary states: "The Kaneohe Bay Regional Council is a community-based institution for guiding natural resources management that is unprecedented in Hawaii. One of its primary duties is facilitating implementation of the Kaneohe Bay Master Plan (1992). . .No other management plan in Hawaii matches the extent of its scope and level of community involvement in its formulation." Mr. John Goody of Belt Collins served as chair of the Kaneohe Bay Task force which originally developed the Kaneohe Bay Master Plan.

c. The Ala Wai Canal Watershed Improvement Project (AWCWIP) is funded by a

Congressional appropriation of $650,000 to the EPA and administered by the State DOH Clean Water Branch. The Ahupua'a Action Alliance and several of its member organizations sit on the Community Advisory Committee and Mr. John Goody of Belt Collins is a member of the Technical Advisory Committee to AWCWIP.

d. The Kailua Bay Advisory Council (KBAC) is currently developing a master plan for water quality improvement for the entire Ko'olaupoko District of Oahu which focuses on the receiving waters of Kaneohe, Kailua and Waimanalo Bays. KBAC is funded by a $3.5 million consent decree settlement with the C&C of Honolulu resulting from a citizen lawsuit over effluent discharge from the Kailua WWTP.

e. These three active initiatives provide real-time models for the development of a Master Plan for water quality improvement within the watersheds that discharge into the Pearl Harbor Estuary. The base costs for the Outfall Replacement could be used as a catylyst to seek additional funding to develop a large scale Master Plan for the entire ecosystem.

Conclusion

The Alliance acknowledges that these recommendations discuss issues that go beyond the mission of Navy Public Works Center and the scope of the consultants contract. However, it is hoped that these comments will be passed on and reviewed by other decision makers to determine whether there is an unprecedented opportunity here to make a major paradigm shift. 1998 marks not only the Centennial of the Annexation of Hawaii but also the final biennium leading to the Next Millenium. If the Navy is willing to open a dialogue with the community on these issues, the Alliance will commit its participation to assist is mobilizing support from other federal, state and county agencies as well as community organizations. Hopefully the dialogue can emerge as part of the decision-making on the Outfall Replacement within the context of the DEIS or perhaps as a parallel process. In either case, it should occur prior to a final commitment is made.

Thank you for this opportunity to comment.

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
(MAKALAPA, HI)
PEARL HARBOR, HAWAII 96860-7300

5090P.1F3C
Ser 231/ 2347
22 JUN 1998

Mr. Stephen T. Kubota
Ahupua'a Action Alliance
44-281 Mikiola Drive
Kaneohe, HI 96744

Dear Mr. Kubota:

Subj: DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS) FOR OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT (WWTP) AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR

Thank you for your letter of January 9, 1998, on the DEIS for the above proposed action. Our responses to your comments that we summarized are provided below.

CONCERNS

Upgrading the Existing Facility

Comment: This option [of additional treatment to remove nutrients] should be fully explored, as suggested by the Environmental Protection Agency (EPA) letter, and included in the comparison tables along with the other options.

Response: Plant expansion to further increase the level of treatment to remove nutrients was rejected early in the process due to cost and the lack of sufficient contiguous space. In addition, the WWTP adjoins an area containing numerous human burials. (This latter item will be added to Section 1.2.) Upgrading the plant to provide nutrient removal would reduce the biological loading on the estuary, rather than relocate the discharge outside of the Pearl Harbor Estuary. It would not reduce the effluent salinity, and hence, would not improve the potential resource value of the effluent.

Comment: What are the costs related to "additional treatment steps" to permit discharges through the existing outfall?

Response: The preliminary cost estimate for upgrading the plant to provide nutrient removal is $59 million, as indicated in Section 2.1.2.2.

Water as a Resource

Comment: The DEIS does not evaluate water as a resource.

Response: Even though reclaimed water with higher chloride levels may be acceptable for specific uses (such as coastal wetlands, coastal strands, and possibly even

aquaculture) in certain areas, no demand currently exists for such water. The requirements for continuous disposal of wastewater from a wastewater treatment plant are such that an assured demand or a reliable backup disposal method is required. The cost to implement effluent reuse from the Wastewater Treatment Plant (WWTP) at Fort Kamehameha is significantly more expensive than other alternatives and cannot be justified by any demonstrable adverse environmental effect that would be avoided by such use.

Comment: The Navy's interest in the Waiahole Ditch case centered on irrigation for agricultural uses within the Blast Zone. Reclaimed water from the Ft. Kam WWTP could supply that need.

Response: It would not be economically feasible to reuse effluent from the WWTP at Fort Kamehameha for irrigation within the Explosive Safety Blast Zone because of the extensive infrastructure system needed for transmission. The Honouliuli WWTP would be a source of much less expensive reclaimed water because of its relatively low chloride content and proximity.

Comment: The 30 year cost analysis for the reuse option is overstated if the projected demand on ground water sources is exceeded in 22 years.

Response: The DEIS evaluates the best case scenario for reuse of effluent from the WWTP at Fort Kamehameha. As stated in Section 2.5.2.3, outfall construction does not preclude future effluent reuse, should conditions change such that the price of non-potable water increases so that the expense of desalination can be recovered, or a market for saline reclaimed water emerges. Under existing and foreseeable pricing policies established by the Board of Water Supply, the costs of effluent desalination cannot be justified.

Integrated Water Resource Management

Comment: The Water Commission further stated: "an integrated water resource plan must be developed to address how we will meet water demand given our dwindling supply." The DEIS does not consider an integrated approach to the problem. The reuse option should be evaluated to consider restoration of the larger landscape and to address environmental justice concerns related to the displacement of traditional agricultural and aquaculture production that historically existed in and around Pearl Harbor.

Response: Development of an Integrated Water Resource Management Plan is a broad policy issue that is beyond the scope of this project-specific EIS.
Environmental Justice

Comment: At the scoping meeting, the Alliance recommended that environmental justice impacts be assessed to include those resulting from the withdrawal of ground water that formerly flowed to the estuary.

Response: The withdrawal of groundwater is not a direct, indirect, or cumulative consequence of the proposed action, and its evaluation is beyond the scope of this document.

Comment: The effluent reuse option focuses only on federal property, i.e., golf courses and airport facilities. At the scoping meeting the Alliance urged the Navy to consider the reuse option to support the civilian population displaced by RIF's and the closure of sugar operations in the surrounding community.

Response: As indicated above, the DEIS evaluates the best case scenario for reuse of effluent from the WWTP at Fort Kamehameha, by assuming that the reclaimed water would be used at the nearest potential reuse areas. Transmission of reclaimed water to more distant reuse areas would increase both the capital and operating costs of the alternative.

REUSE OPTION

The Reuse Option Should be Considered the Preferred Alternative

Comment: In testimony before the Water Commission in the Waiahole Ditch CCH, Dr. Bruce Anderson states that these guidelines (DOH Guidelines for the Treatment and Use of Reclaimed Water, November 22, 1993) are "not set rules, do not have the force of law, and do not actually prohibit any uses of reclaimed water."

Response: Although the DOH Guidelines for the Treatment and Use of Reclaimed Water are not enforceable by law and do not actually prohibit any uses of reclaimed water, they are considered during DOH reviews of effluent reuse proposals and should be followed in the best interests of public health.

Cost Analysis for the Reuse Option is Overstated

Comment: Cost analysis is based on comparisons to current costs of non-potable water. It should be based on projected costs of potable water.

Response: As indicated above, the DEIS evaluates the best case scenario for reuse of effluent from the WWTP at Fort Kamehameha.. The cost analysis of the reuse alternative is based on comparisons to the current costs of non-potable water, because projected future costs of both potable and non-potable water are unknown. It would be difficult to accurately predict what these projected costs would be, and unwise to commit a large investment of public funds based upon speculative future pricing.

Coastal Aquaculture/Agriculture

Comment: Brackish water is suitable not only for edible aquaculture/agricultural products but can also be used to support commercial production of ornamental plants, native species and other coastal strand biota to create a vegetated buffer around

the WQLS to retard erosion, sedimentation and nutrient loading. Commercial aquaculture/agriculture will increase nutrient uptake and removal with positive benefits to the receiving waters while providing a source of revenue to off-set the additional costs of treatment for reuse.

Response: As indicated in our above response under *Water as a Resource*, although brackish reclaimed water may be acceptable for the specific uses that you have identified, no demand currently exists for such water. The requirements for continuous disposal of wastewater from a wastewater treatment plant are such that an assured demand or a reliable backup disposal method is required. As indicated in the DEIS, construction of the proposed outfall does not preclude future reuse, should demand for the brackish effluent develop sufficiently to offset the costs of developing the necessary reuse infrastructure.

Reuse Sites

Comment: New housing developments on Ford Island as well as the proposed USS Missouri memorial are ideal sites for installation of dual transmission infrastructure. Reclaimed water can be used during construction, for maintenance, landscaping, fire control, toilet flushing, etc. Agriculture/aquaculture uses within the Blast Zone and the Waipio peninsula should explore revenue generating crops to off-set the additional costs of a delivery system.

Response: As indicated earlier under *Water as a Resource*, the DEIS evaluates the best case scenario for reuse of effluent from the WWTP at Fort Kamehameha. The additional costs of building transmission infrastructure to Ford Island and the Waipio Peninsula would increase the project costs without increasing the market value of the reclaimed water. An assured demand or reliable backup effluent disposal method would be required.

Comment: The Naval/FAA Reservation in Pu'uloa is located in an area that was historically a salt pond/mill and should be evaluated for brine disposal.

Response: As with effluent reuse, the reuse alternative incorporated the least-cost method of brine disposal that would meet existing regulations.

RECOMMENDATIONS

Outfall Replacement Option

Comment: Use the Outfall Replacement option as the cost-effective "fall-back" alternative. The costs related to the Outfall replacement can be used as a benchmark to "negotiate" for additional sources of funding to implement other options as discussed below.

Response: Based upon our analysis, as presented in the DEIS, outfall replacement is the environmentally preferred alternative. It is also the most cost-effective alternative.

Plant Upgrade Option

Comment: Develop a detailed analysis of the Plant Upgrade option to allow better comparison with the other alternatives, especially its relationship to the reuse option.

Response: As stated in our above response under *Upgrading of the Existing Facility*, plant expansion to further increase the level of treatment to remove nutrients was rejected early in the process due to cost and the lack of sufficient contiguous space. (The wastewater treatment plant adjoins an area containing numerous human burials.) Upgrading the plant to provide nutrient removal would reduce the biological loading on the estuary, but it would not remove the discharge from the estuary. It would not reduce the effluent salinity, and therefore would not improve the potential resource value of the effluent.

Comment: The costs for plant upgrade may be a function of improvements to the supply-side input to the system such as improvements to the industrial treatment facility, efficiency to the delivery transmission system and user education related to water conservation, household chemicals and alternative disposal of hazardous materials. These functions are appropriately part of an integrated water resource management strategy coupled with community based watershed management.

Response: While we acknowledge the potential benefits of an integrated water source management strategy and community-based watershed management, these are broad policy issues that are beyond the scope of this project-specific EIS.

Reuse Option

Comment: Re-examine the Reuse Option in light of the Water Commission's decision in the Waiahole Ditch Contested Case Hearings, especially those findings of fact related to water as a resource (cost analysis) and the potential for aquaculture/agriculture reuse below the H-1 Freeway and projected development within the Pearl Harbor complex, especially Ford Island and the USS Missouri memorial.

Response: As indicated in our above response under *Water as a Resource*, the DEIS evaluates the best case scenario for reuse of effluent from the WWTP at Fort Kamehameha. Although brackish reclaimed water may be acceptable for specific uses, no demand currently exists for such water, and effluent desalination would make the reclaimed waster considerably more costly than other sources of non-potable water. Construction of the proposed outfall does not preclude future reuse, on Ford Island or elsewhere, should demand for either brackish or desalinated effluent develop sufficiently to offset the costs of building and operating the necessary reuse infrastructure.

Environmental Credit Option

Comment: Develop and expanded analysis of the total water/pollution budget for the entire WQLS of the Pearl Harbor estuary. Seek EPA support for using an "environmental credit" approach to evaluating the impact of the current outfall if improvement can be made to the overall Pearl Harbor WQLS.

Response: The development of a total water/pollution budget for the entire Pearl Harbor Estuary and of an "environmental credit" approach to managing water quality in the Pearl Harbor Estuary are broad policy issues that are beyond the scope of this project-specific EIS.

Community Based Watershed Management

Comment: Explore the feasibility of establishing a joint DOD/Civilian Community Based Watershed Management Plan for the Pearl Harbor Estuary.

Response: The feasibility of establishing a joint DOD/Civilian Community Based Watershed Management Plan is a broad policy issue that is beyond the scope of this project-specific EIS.

We appreciate your recommendations and the thought that went into them. These comments in large measure exceed the scope of the matter under consideration. We will be providing additional information about the alternative for upgrading the plant in the final EIS. However, watershed management and integrated water resource management are issues that provide context for the proposed action, but are not a consequence of it. We have accounted for water and watershed conditions as they affect the proposed action, including demand for potable water, and water quality in the estuary.

Should you have any questions, please contact Mr. Gary Kasaoka (Code 231GK) at 471-9338 or by facsimile transmission at 474-5909.

Sincerely,

Melvin N. Kaku

MELVIN N. KAKU
Director
Environmental Planning Division

Copy to:
Belt Collins Hawaii
680 Ala Moana Boulevard, First Floor
Honolulu, HI 96813

United States Department of the Interior

OFFICE OF THE SECRETARY
Office of Environmental Policy and Compliance
600 Harrison Street, Suite 515
San Francisco, California 94107-1376

January 12, 1998

ER 97/0680

Gary Kasaoka (231GK0)
Pacific Division
Naval Facilities Engineering Command
Pearl Harbor, Hawaii 96860-7300

Dear Mr Kasaoka:

The Department of the Interior has reviewed the Draft Environmental Impact Statement (DEIS) for Outfall Replacement for the Wastewater Treatment Plant at Fort Kamehameha, Pearl Harbor, Hawaii. The following comments are provided for your information and use when preparing the Final Environmental Impact Statement (FEIS).

GENERAL COMMENTS
The proposed action would re-align and extend the Fort Kamehameha Wastewater Treatment Plant outfall approximately 2.4 miles further offshore to discharge at a depth of approximately 46 meters. This re-alignment proposal would affect a variety of habitats, including shorelines, shallow nearshore areas, reef flat, and marine benthic communities. Trust resources present in the project area include the endangered Hawaiian stilt (*Himantopus mexicanus knudseni*), federally listed under the Endangered Species Act of 1973, as amended (ESA), and a variety of migratory shorebirds protected under the Migratory Bird Treaty Act (MBTA).

Common shorebirds, protected under the MBTA, include the Pacific golden plover (*Pluvialis fulva)*, ruddy turnstone (*Arenaria interpres*), sanderling (*Calidris alba*), and wandering tattler (*Heteroscelus incanus*). Nearshore shallows and islets in the project area provide important feeding habitat for these species. While stilt species are potentially present all year, migratory shorebirds are generally present from mid-August through early May.

The federally listed threatened green sea turtle (*Chelonia mydas*) is under joint jurisdiction of U.S. Fish and Wildlife Service and National Marine Fisheries Service and is occasionally seen in the area. Coral reefs and their associated fish and invertebrate species are also present in the project area and would be impacted by the proposed project.

In addition to mitigation already proposed in the DEIS, the Department requests the FEIS include the following additional measures:

- to the extent possible, confine construction activities in bird habitat to summer months

(early May through mid-August) when migratory shorebirds are generally not present;

- minimize all disturbances to islets and shorelines used by shorebirds and stilts and keep all activities as far away from these areas as possible;

- to the extent possible, utilize directional, underground drilling (as described in the draft EIS) in bird habitat and in reef crest and reef slope areas where coral is most abundant and diverse;

- utilize best management practices to reduce turbidity and siltation, including the use of silt curtains and provisions for temporary storage and dewatering of dredged materials behind an impermeable berm above the influence of the tides.

SPECIFIC COMMENTS
Page 4-40, Section 4.4.3 Protected Species. This section only discusses species protected under the Endangered Species Act. However, migratory birds are also protected under federal law (i.e., the Migratory Bird Treaty Act) and should be discussed here as well.

Page 4-42, Section 4.4.3.3 Construction Impacts and Mitigation. Please refer to the comment on additional mitigation measures requested in the General Comments section.

SUMMARY COMMENTS
Overall, the Department has no objection to the proposed action, provided that the above measures are incorporated and comments are addressed in the project and EIS respectively.

Thank you for the opportunity to comment on the proposed project.

Sincerely

Patricia A Port

Patricia Sanderson Port
Regional Environmental Officer

cc:
Director, OEPC, w/original incoming
Regional Director, FWS, Region I

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
(MAKALAPA, HI)
PEARL HARBOR, HAWAII 96860-7300

5090P.1F3C
Ser 231/2349
22 JUN 1998

Ms. Patricia Sanderson Port
Environmental Policy and Compliance
U.S. Department of the Interior
600 Harrison Street, Suite 515
San Francisco, CA 94107-1376

Dear Ms. Port:

Subj: DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS) FOR OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR

Thank you for your letter of January 12, 1998, containing your agency's comments on the DEIS for the above proposed action. Our responses to your comments are as follows:

a. Comment: This re-alignment proposal would affect a variety of habitats, including shorelines, shallow nearshore areas, reef areas, reef flat, and marine benthic communities. Trust resources present in the project area include the endangered Hawaiian stilt (*Himantopus mexicanus knudseni*), federally listed under the Endangered Species Act of 1973, as amended (ESA), and a variety of migratory shorebirds protected under the Migratory Bird Treaty Act (MBTA).

Common shorebirds, protected under the MBTA, include the Pacific golden plover (*Pluvialis fulva*), ruddy turnstone (*Arenaria interpres*), sanderling (*Calidris alba*), and wandering tattler (*Heteroscelus incanus*). Nearshore shallows and islets in the project area provide important feeding habitat for these species. While stilt species are potentially present all year, migratory shorebirds are generally present from mid-August through early May.

Response: The final EIS (FEIS) will be revised to clarify that the black-necked stilt mentioned is the Hawaiian stilt.

Revision of the DEIS: Section 3.5.2.1 will be revised to clarify the fact that the black-necked stilt mentioned in the text actually is also known as the Hawaiian stilt.

The third paragraph of Section 3.5.2.1 will be revised to read, "Past surveys revealed the presence of several other bird species in the area, such as the Hawaiian stilt (*Himantopus mexicanus knudseni*), a listed species."

b. Comment: The federally listed threatened green sea turtle (*Chelonia mydas*) is under joint jurisdiction of U.S. Fish and Wildlife Service and National Marine Fisheries Service and is occasionally seen in the area. Coral reefs and their

associated fish and invertebrate species are also present in the project area and would be impacted by the proposed project.

Response: The fact that green sea turtles, corals, and reef fish, and other invertebrate species have been observed in the area is stated in Section 3.5.2.2. The information provided will be incorporated into this section.

Revision of the DEIS: The following statement will be added at the end of the second paragraph of Section 3.5.2.2: "The green sea turtle is considered a threatened species and is under joint jurisdiction of the U.S. Fish and Wildlife Service and National Marine Fisheries Service."

c. Comment: In addition to mitigation already proposed in the DEIS, the Department requests the FEIS include the following additional measures:

(1) To the extent possible, confine construction activities in bird habitat to summer months (early May through mid-August) when migratory shorebirds are generally not present;

(2) Minimize all disturbances to islets and shorelines used by shorebirds and stilts and keep all activities as far away from these areas as possible;

(3) To the extent possible, utilize directional, underground drilling (as described in the draft EIS) in bird habitat and in reef crest and reef slope areas where coral is most abundant and diverse;

(4) Utilize best management practices to reduce turbidity and siltation, including the use of silt curtains and provisions for temporary storage and dewatering of dredged materials behind an impermeable berm above the influence of the tides.

Response: The requested additional construction mitigation measures do not conflict with any statements made in the DEIS and will be incorporated into the FEIS.

Revision of the DEIS: Section 4.4.3.3 will be revised to include the additional construction mitigation measures.

d. Comment: Page 4-40. Section 4.4.3 Protected Species. This section only discusses species protected under the Endangered Species Act. However, the migratory birds are also protected under federal law (i.e., the Migratory Bird Treaty Act) and should be discussed here as well.

Response: The Navy strives to reduce adverse impacts on migratory birds in the course of its planning for and engaging in activities. With regard to this project, the Navy does not foresee any situation that might result in an unintended or intentional "taking" of common migratory shorebirds protected under the MBTA.

Revision of the DEIS: Section 2.3.2.3 will indicate that migratory birds are protected under the Migratory Bird Treaty Act, but that any unintended or intentional "taking" of the same is not anticipated or contemplated. Also, the first paragraph of Section 4.4.3 will be revised to read, "This section discusses the impacts on flora and fauna, including listed (threatened and endangered) species, protected migratory shorebird species, and their habitat."

The second bullet point of the second paragraph will be revised to read, "During construction, birds, including the endangered Hawaiian stilt (*Himantopus mexicanus knudseni*) and any migratory shorebirds, may be displaced from foraging areas of the offshore islets and the reef flats. However, given the relatively low numbers of individuals noted and the availability of nearby similar undisturbed habitat, the degree of impacts to birds will not be significant. The mitigation of such impacts is discussed in Section 4.4.3.3."

Should you have any questions, please contact Mr. Gary Kasaoka (Code 231GK) at (808) 471-9338 or by facsimile transmission at (808) 474-5909.

Sincerely,

Melvin N. Kaku

MELVIN N. KAKU
Director
Environmental Planning Division

Copy to:
Belt Collins Hawaii
680 Ala Moana Boulevard, First Floor
Honolulu, HI 96813

DEPARTMENT OF PARKS AND RECREATION
CITY AND COUNTY OF HONOLULU
650 SOUTH KING STREET, 10TH FLOOR • HONOLULU, HAWAII 96813
PHONE: (808) 523-4182 • FAX: (808) 523-4054

JEREMY HARRIS
MAYOR

WILLIAM D. BALFOUR, JR
DIRECTOR

MICHAEL T. AMII
DEPUTY DIRECTOR

January 22, 1998

Mr. Gary Kasaoka (Code 231GK)
Pacific Division
Naval Facilities Engineering Command
Building 258, Makalapa
Pearl Harbor, Hawaii 96860-7300

Dear Mr. Kasaoka:

Subject: Draft Environmental Impact Statement (DEIS) for Outfall Replacement for Wastewater Treatment Plant at Fort Kamehameha (WWTP), Navy Public Works Center Pearl Harbor, Hawaii

We have reviewed the DEIS referenced above. We understand that the proposed deep water outfall replacement will be an improvement relative to the existing outfall into the Pearl Harbor estuary. However, a few concerns remain.

The executive summary states that effluent from the WWTP presently receives secondary treatment and is sand filtered. It is not clear what changes, if any, the proposed project will cause to the quality and disinfection of the treated effluent. We suggest that this information be explicitly stated in the executive summary.

We are concerned about possible impacts to coastal beaches and recreation areas from an accidental discharge of untreated or partially treated sewage to the ocean. We are also concerned about the impact of a possible accidental break in the proposed outfall close to the shore. Please discuss these potential impacts in your final EIS and disclose what contingency plans have been made to mitigate these impacts if they should occur. In this regard, it would be helpful if your report included a chart showing marine currents and analyzed the impact that accidental discharges would have on the ocean and coastal environments. Also, please state in your report the estimated probability that accidents such as these may occur.

Please disclose to what extent the proposed project, both during and after construction, may generate ciguatera blooms which could contaminate fish taken from near shore waters.

As one of your alternative actions in the final EIS, please include an analysis of *combining* outfall disposal with upland reuse of effluent, such as by enhancing and using the existing marine wetlands by Hickam Harbor.

Please call Mr. Terry Hildebrand, Planner in our Advance Planning Branch, at 523-4272 if you have any questions.

Sincerely,

W. D. Balfour

WILLIAM D. BALFOUR, JR.
Director

WDB:ei

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
(MAKALAPA, HI)
PEARL HARBOR, HAWAII 96860-7300

5090P.1F3C
Ser 231/1683
01 MAY 1998

Mr. William D. Balfour, Jr.
Department of Parks and Recreation
City and County of Honolulu
650 South King Street, 10th Floor
Honolulu, HI 96813

Dear Mr. Balfour:

Subj: DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS) FOR OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT (WWTP)AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR, HAWAII

Thank you for your written comments of January 22, 1998, on the DEIS for the above referenced action. Our response to your comments are as follows:

Comment: The executive summary states that effluent from the WWTP presently receives secondary treatment and is sand filtered. It is not clear what changes, if any, the proposed project will cause to the quality and disinfection of the treated effluent. We suggest that this information be explicitly stated in the executive summary.

Response: The proposed action will not affect the quality or disinfection of the effluent, because the treatment processes will not be affected by construction or operation of the proposed outfall.

Revision to the DEIS: The executive summary will be revised to include this information.

Comment: We are concerned about possible impacts to coastal beaches and recreation areas from an accidental discharge of untreated or partially treated sewage to the ocean. We are also concerned about the impact of a possible accidental break in the proposed outfall close to the shore. Please discuss these potential impacts in your final EIS and disclose what contingency plans have been made to mitigate these impacts if they should occur. In this regard, it would be helpful if your report included a chart showing marine currents and analyzed the impact that accidental discharges would have on the ocean and coastal environments. Also, please state in your report the estimated probability that accidents such as these may occur.

Response: Neither the proposed action nor alternatives will affect the potential for accidental discharge of untreated or partially treated sewage to the ocean. The purpose of this DEIS is not to evaluate the operations and maintenance procedures of the wastewater treatment plant but to provide the Assistant Secretary of the Navy with enough information to decide the following:

a. Whether or not to replace the outfall.

b. If the existing outfall is to be replaced, which of the alternatives will be used to dispose of the effluent.

Regarding your concern about the impact of a possible accidental break in the proposed outfall close to the shore, the outfall design will provide durability at least equal to that of sewers carrying raw sewage. The entire outfall, with the possible exception of the diffuser end of the outfall, will be buried below grade as described in Section 2.3.4.1 and 2.3.4.2. A near shore break of the outfall can only be anticipated as a result of a catastrophic event, such as an earthquake. In such emergency situations, the existing outfall, if not damaged, could be used to dispose of effluent until the proposed outfall is repaired.

In addition, as stated in Section 4.4.6.7, possible damage to the diffuser end of the outfall pipe from boat anchors will be mitigated by adding the location of this underwater obstruction to National Oceanic and Atmospheric Administration nautical charts.

Revision to the DEIS: None.

Comment: Please disclose to what extent the proposed project, both during and after construction, may generate ciguatera blooms which could contaminate fish taken from near shore waters.

Response: Although it has been postulated that excavation activities may result in increased incidences of ciguatera due to the increased "bared" substratum, an actual cause-and-effect relationship has not been documented. The reef flat surface already consists of "bared" rubble beds, which appear to have the potential to act as settling sites for the host algae on which the benthic dinoflagellate responsible for ciguatera occur. Hence, the proposed construction activities appear to add little to the overall abundance of "bared" substratum.

Revision to the DEIS: None.

Comment: As one of your alternative actions in the final EIS, please include an analysis of combining outfall disposal with upland reuse of effluent, such as by enhancing and using the existing marine wetlands by Hickam Harbor.

Response: As stated in Section 5.2.3, outfall construction does not preclude future effluent reuse when economically feasible methods of reuse of saline effluent become available. Currently, no demand for the saline effluent has been identified. Near shore discharge, such as to the existing marine wetlands, would not meet the stated purpose and need (Section 1.2) or comply with existing environmental regulations.

Subj: DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS) FOR OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT (WWTP) AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR, HAWAII

Revision to the DEIS: None.

Due to discovery of a soft-soil condition along the original outfall alignment proposed in the DEIS, a new alignment around the soft spot is being designed. A supplemental draft environmental impact statement (SDEIS) will be issued in the fall of this year to cover the new engineering challenge. All recipients of the original DEIS will remain on the distribution list to receive the SDEIS and other subsequent documents related to the EIS

Should you have any questions, please contact Mr. Gary Kasaoka (Code 231GK) at 471-9338 or by facsimile transmission at 474-5909.

Sincerely,

Melvin N. Kaku

MELVIN N. KAKU
Director
Environmental Planning Division

Copy to:
Belt Collins Hawaii
680 Ala Moana Boulevard, 1st Floor
Honolulu, HI 96813

BENJAMIN J. CAYETANO
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF HEALTH
P.O. BOX 3378
HONOLULU, HAWAII 96801

LAWRENCE MIIKE
DIRECTOR OF HEALTH

In reply, please refer to:

January 29, 1998

96-157A/epo

Mr. Stanley Y. Uehara, Acting Director
Environmental Planning Division
Department of the Navy
Pacific Division
Naval Facilities Engineering Command
(Makalapa, HI)
Pearl Harbor, Hawaii 96860-7300

Dear Mr. Uehara:

Subject: DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS)
Project: Proposed Outfall Replacement for Wastewater Treatment Plant
Location: Fort Kamehameha, Navy Public Works Center Pearl Harbor, Oahu, Hawaii

Thank you for allowing us to review and comment on the subject project. The Wastewater Branch had submitted an earlier response in a letter dated December 17, 1997. We have the following additional comments to offer:

Clean Water Branch

The applicant shall contact the U.S. Army Corps of Engineers to identify which Federal permit (including a Department of Army permit) is required for this project. Pursuant to Section 401(a)(1) of the Federal Water Pollution Act (commonly known as the "Clean Water Act"), a Section 401 Water Quality Certification is required for "Any applicant for Federal license or permit to conduct any activity which may result in any discharge into the navigable waters..."

A National Pollutant Discharge Elimination System (NPDES) general permit coverage is required for each of the following activities which discharges into State Waters:

1. Discharge of hydrotesting water; and

2. Discharge of construction dewatering effluent.

The applicant is required to apply for a modification of their Individual NPDES Permit if there is any change (i.e., additional mass loading) of the wastewater discharge from the facility into State waters. The applicant shall also provide an anti-degradation analysis for any additional mass loading to the Department of Health for review and approval.

Application forms for those discharges that need to obtain a Water Quality Certification, General Permit Coverage, and/or Individual Permit will be provided upon request.

Should you have any questions regarding this matter, please contact Ms. Joanna L. Seto of the Clean Water Branch, Engineering Section at 586-4309.

Sincerely,

BRUCE S. ANDERSON, Ph.D.
Deputy Director for Environmental Health

c: CWB

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
(MAKALAPA, HI)
PEARL HARBOR, HAWAII 96860-7300

5090P.1E3C
Ser 231/ 2332

18 JUN 1998

Bruce Anderson, Ph.D., Deputy Director
Environmental Health Division
Department of Health
P.O. Box 3378
Honolulu, HI 96801

Dear Dr. Anderson:

Subj: DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS) FOR OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR

Thank you for your letter of January 29, 1998, in which you commented on the DEIS for the above referenced action. In response to your comments on the permit requirements, the Navy will take the following actions:

a. Contact the U.S. Army Corps of Engineers in an attempt to identify the Federal permits that will be required by the project;

b. Obtain a Section 401 Water Quality Certification from your agency; and

c. At the appropriate time, the operator of the wastewater treatment plant will apply for a modification of the Individual National Pollutant Discharge Elimation System permit, if there is a change (i.e., additional mass loading) in the wastewater discharge from the facility into State waters.

Should you have any questions, please contact Mr. Gary Kasaoka (Code 231GK) at 471-9338 or by facsimile transmission at 474-5909.

Sincerely,

Melvin N. Kaku

MELVIN N. KAKU
Director
Environmental Planning Division

Copy to:
Belt Collins Hawaii
680 Ala Moana Boulevard, First Floor
Honolulu, HI 96813

Appendix II-k

Amendment to Initial Response Letter

Amendment to Initial Response Letter

A second letter was sent to some of the commentors to amend information provided in the initial response letter. The body of the letter is as follows:

> "Contrary to an earlier notice you may have received that a Supplemental Draft Environmental Impact Statement (SDEIS) would be prepared to accommodate a new outfall alignment necessitated by a soft-soil condition found along the original alignment described earlier in the Draft Environmental Impact Statement for this project, the Navy has determined that an SDEIS will not be needed. Through subsequent investigations it was found that only a relatively short segment of the original alignment will be affected. The Navy's plan is to proceed as originally scoped for this National Environmental Policy Act (NEPA) action. Thus, the next NEPA document for this project will be the Final Environmental Impact Statement (FEIS), which is scheduled to be available in the fall of this year with a following 30 day comment period.
>
> As an active participant in this NEPA process on the Navy's distribution list, you will automatically receive a copy of the FEIS for review. Announcement on the availability of the FEIS will be made by a notice in the *Federal Register* and by legal advertisements in the two local newspapers: **Honolulu** *Star-Bulletin* and **Honolulu** *Advertiser*. A notice of availability of the FEIS will also appear in the Office of Environmental Quality Control's *The Environmental Notice* at about the same time.
>
> We apologize for any inconvenience the earlier SDEIS announcement may have caused you, and we thank you for actively participating in this NEPA process."

The following people/organizations received this additional letter:

- Jonathan K. Shimada, Ph.D., Department of Public Works, City and County of Honolulu
- Thomas T. Fujikawa, Harbors Division Administrator, Hawaii Department of Transportation
- Patrick T. Onishi, Planning Department, City and County of Honolulu
- Kenneth Sprague, Department of Wastewater Management, City and County of Honolulu
- Board of Water Supply
- Jan Sullivan, Department of Land Utilization, City and County of Honolulu

- Dean Y. Uchida, Land Division Administration, Department of Land and Natural Resources
- Dennis Tulang, Department of Health Wastewater Branch, State of Hawaii
- U.S. Army Corps of Engineers (CEPOD ET PP)
- Harold K. Nagato, Best Industries USA, Inc.
- William D. Balfour, Jr., Department of Parks and Recreation, City and County of Honolulu

Appendix II-I

FEIS Distribution List

MILITARY

MR MICHAEL F MCGHEE
CHIEF ENVIRONMENTAL FLIGHT
15 CES CEB
75 H STREET
HICKAM AFB HI 96853-5233

MR STEPHAN ZAK
HARBOR MASTER
15 SVS SVRO
900 HANGAR AVE
HICKAM AFB HI 96853-5426

OFFICER IN CHARGE
15 CES CEVP
75 H STREET
HICKAM AFB HI 96853-5233

OFFICER IN CHARGE
15 CES CEC
75 H STREET
HICKAM AFB HI 96853-5233

MR BOB LANDIS
HQ PACAF CEVP
25 E STREET SUITE D 306
HICKAM AFB HI 96853-5412

S J REDMAN
15 ABW CC
800 SCOTT CIRCLE
HICKAM AFB HI 96853-5328

PUBLIC AFFAIRS OFFICER
15 ABW PAI
800 SCOTT CIRCLE
HICKAM AFB HI 96853-5328

LTC HERRERA (MAYOR)
FORT KAMEHAMEHA FAMILY HOUSING ASSOC
26 WORCHESTER AVE
HICKAM AFB HI 96818

DIRECTOR OF HOUSING
15 CES CEH
900 HANGAR AVENUE
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COMMANDER
ATTN APEN
US ARMY PACIFIC
FORT SHAFTER HI 96858-5100

COMMANDER DIVISION ENGINEER
US ACOE PACIFIC OCEAN DIVISION
BUILDING 230
FORT SHAFTER HI 96858-5440

GEORGE YOUNG
US ARMY CORPS OF ENGINEERS HONOLULU DIST
ATTN REGULATORY BRANCH CEPOH CO OR
BUILDING 230
FORT SHAFTER HI 96858-5440

DIRECTOR OF ENGINEERING
DEPARTMENT OF THE ARMY
US ARMY ENGINEER DISTRICT HONOLULU
FORT SHAFTER HI 96858-5440

ARMY DIRECTORATE OF PUBLIC WORKS
ATTN ENVIRONMENTAL MANAGEMENT OFFICE
US ARMY GARRISON HAWAII
SCHOFIELD BARRACKS HI 96857-5000

COMMANDER
US COAST GUARD
14TH COAST GUARD DISTRICT
300 ALA MOANA BOULEVARD
HONOLULU HI 96850

US ARMY CORPS OF ENGINEERS
JAPAN DISTRICT
CEPOJ PP E
APO AP 96338-5010

CITY

THE HONORABLE JEREMY HARRIS
MAYOR OF THE CITY AND COUNTY OF HONOLULU
CITY HALL
530 SOUTH KING STREET RM 300
HONOLULU HI 96813

COUNCILMAN ROMY M CACHOLA
CITY COUNCIL
530 SOUTH KING STREET RM 202
HONOLULU HI 96813

COUNCILMAN GARY OKINO
CITY COUNCIL
530 SOUTH KING STREET RM 202
HONOLULU HI 96813

MR WILLIAM CLARK
AIEA NEIGHBORHOOD BOARD
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AIEA HI 96701

MR JOEL KAYE
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98 1820 NORTH KAAHUMANU ST
PEARL CITY HI 96782

MR MARK TAYLOR
ALIAMANU NEIGHBORHOOD BOARD
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HONOLULU HI 96818

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DEPARTMENT OF ENVIRONMENTAL SVCS
CITY AND COUNTY OF HONOLULU
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MR RANDALL FUJIKI DIRECTOR
DEPARTMENT OF PLANNING AND PERMITTING
CITY AND COUNTY OF HONOLULU
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MR CLIFFORD S JAMILE MANAGER AND CHIEF ENGR
BOARD OF WATER SUPPLY
630 SOUTH BERETANIA STREET
HONOLULU HI 96813

MR WILLIAM D BALFOUR JR DIRECTOR
DEPARTMENT OF PARKS AND RECREATION
CITY AND COUNTY OF HONOLULU
650 SOUTH KING STREET 10TH FLOOR
HONOLULU HI 96813

MS RAE M LOUI P E
DEPARTMENT OF DESIGN AND CONSTRUCTION
CITY AND COUNTY OF HONOLULU
650 SOUTH KING STREET
HONOLULU HI 96813

STATE

THE HONORABLE NORMAN SAKAMOTO
HAWAII SENATE
STATE CAPITOL
415 SOUTH BERETANIA STREET
HONOLULU HI 96813

THE HONORABLE DAVID Y IGE
HAWAII SENATE
STATE CAPITOL
415 SOUTH BERETANIA STREET
HONOLULU HI 96813

THE HONORABLE RON MENOR
HAWAII SENATE
STATE CAPITOL
415 SOUTH BERETANIA STREET
HONOLULU HI 96813

THE HONORABLE ROBERT BUNDA
STATE CAPITOL
415 SOUTH BERETANIA STREET
HONOLULU HI 96813

THE HONORABLE BENJIMAN CABAROS
HAWAII HOUSE OF REPRESENTATIVES
STATE CAPITOL
415 SOUTH BERETANIA STREET
HONOLULU HI 96813

THE HONORABLE BOB MC DERMOTT
HAWAII HOUSE OF REPRESENTATIVES
STATE CAPITOL
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THE HONORABLE ROY M TAKUMI
HAWAII HOUSE OF REPRESENTATIVES
STATE CAPITOL
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MR GILBERT COLOMA-AGARAN
CHAIRPERSON
C/O DEPT OF LAND AND NATURAL
RESOURCES
STATE OF HAWAII
PO BOX 621
HONOLULU HI 96809

MR THOMAS ARIZUMI CHIEF
ENVIRONMENTAL MANAGEMENT DIVISION
DEPARTMENT OF HEALTH
919 ALA MOANA BLVD RM 300
HONOLULU HI 96801

MR DENNIS TULANG CHIEF
WASTEWATER BRANCH
DEPARTMENT OF HEALTH
919 ALA MOANA BLVD RM 309
HONOLULU HI 96801

MR DENIS LAU CHIEF
CLEAN WATER BRANCH
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MR WILFRED K NAGAMINE CHIEF
CLEAN AIR BRANCH
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DR BRUCE S ANDERSON DIRECTOR
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MR DEAN UCHIDA ADMINISTRATOR
LAND DIVISION
DEPT OF LAND AND NATURAL RESOURCES
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MR THOMAS FUJIKAWA CHIEF
HARBORS DIVISION
DEPARTMENT OF TRANSPORTATION
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MR DAVID BLANE DIRECTOR
STATE OF HAWAII OFFICE OF PLANNING
DEPT BUSINESS ECONOMIC DEVELOPMENT
& TOURISM
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HONOLULU HI 96804

MS CAROLYN IMAMURA EXECUTIVE
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PACIFIC BASIN DEVELOPMENT COUNCIL
711 KAPIOLANI BLVD SUITE 1075
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MS JOLYN G TAMURA STATE ARCHIVIST
ARCHIVES DIVISION
DEPT OF ACCOUNTING AND GENERAL
SERVICES
IOLANI PALACE GROUNDS
HONOLULU HI 96813

MR WILLIAM KC WONG CHIEF
SAFE DRINKING WATER BRANCH
DEPARTMENT OF HEALTH
919 ALA MOANA BLVD RM 308
HONOLULU HI 96813

MR COLIN KIPPN DEPUTY ADMINISTRATOR
STATE HISTORIC PRESERVATION DIVISION
DEPT OF LAND AND NATURAL RESOURCES
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KAPOLEI HI 96707

MR SABASTIAN ELOOT
LAND AND NATURAL RESOURCES
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MR WILLIAM DEVICK ADMINISTRATOR
DLNR AQUATIC RESOURCES DIVISION
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MR ANDREW MONDEN CHIEF ENGINEER
WATER AND LAND DEVELOPMENT BRANCH
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DIRECTOR
SEA GRANT COLLEGE PROGRAM
UNIVERSITY OF HAWAII
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2540 DOLE STREET HOLMES HALL 283
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MR JOHN T HARRISON PHD ENVIR COORD
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HEAD LIBRARIAN
ATTN MS FLORIANA COFMAN
PEARL CITY PUBLIC LIBRARY
1138 WAIMANO HOME ROAD
PEARL CITY HI 96782

HEAD LIBRARIAN
ATTN MS BERYL GOO
EWA BEACH PUBLIC AND SCHOOL LIBRARY
91 950 NORTH ROAD
EWA BEACH HI 96706

HEAD LIBRARIAN
AIEA PUBLIC LIBRARY
99 143 MOANALUA ROAD
AIEA HI 96701

HEAD LIBRARIAN
SALT LAKE MOANALUA PUBLIC LIBRARY
3225 SALT LAKE BLVD
HONOLULU HI 96818

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GOVERNOR OF HAWAII
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MR DAN QUINN ACTING ADMINISTRATOR
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US DEPARTMENT OF THE INTERIOR
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PACIFIC ISLANDS CONTACT OFFICE
US ENVIRONMENTAL PROTECTION AGENCY
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HONOLULU HI 96813

THE HONORABLE DANIEL K INOUYE
US SENATE PRINCE KUHIO BUILDING
300 ALA MOANA BLVD ROOM 7212
HONOLULU HI 96850

THE HONORABLE DANIEL K AKAKA
US SENATE PRINCE KUHIO BLDG
300 ALA MOANA BLVD ROOM 3106
HONOLULU HI 96850

THE HONORABLE NEIL ABERCROMBIE
US HOUSE OF REPRESENTATIVES
300 ALA MOANA BLVD ROOM 4104
HONOLULU HI 96850

THE HONORABLE PATSY T MINK
US HOUSE OF REPRESENTATIVES
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US ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 HAWTHORNE STREET
SAN FRANCISCO CA 94105-3901

DIRECTOR OFFICE OF ENVIRO POLICY & COMPLIANCE
US DEPARTMENT OF THE INTERIOR
MAIN INTERIOR BLDG MS 2340
1849 C STREET NW
WASHINGTON D C 20240 *(6 COPIES)*

MS TWEET COLEMAN
FAA PACIFIC REPRESENTATIVE
FEDERAL AVIATION ADMINISTRATION
PO BOX 50109
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INDIVIDUAL

MR BOB ROCHELEAU
SEA ENGINEERING
MAKAI RESEARCH PIER
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MR PAUL UYEDA
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286 KALIHI STREET
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44 281 MIKIOLA DRIVE
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MR JOHN GEDDIE
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46 196 YACHT CLUB STREET
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MR DWIGHT OKAWA
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P O BOX 185
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MS TONI AULD YARDLEY
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MS MARIE TERRI
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MR MYRON NOMURA
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SIERRA CLUB HAWAII CHAPTER
PO BOX 2577
HONOLULU HI 96803

EARTH JUSTICE LEGAL DEFENSE FUND
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HONOLULU HI 96813

EARTHTRUST
AIKAHI PARK SHOPPING CENTER
25 KANEOHE BAY DRIVE SUITE 205
KAILUA HI 96734

LIFE OF THE LAND
1111 BISHOP STREET SUITE 503
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BLUE OCEAN PRESERVATION SOCIETY
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EXECUTIVE DIRECTOR
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MR JOHN REPPUN
HUI MALAMA AINA O KOOLAU
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KANEOHE HI 96744

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KAILUA HI 96734

CONSERVATION COUNCIL FOR HAWAII
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HONOLULU HI 96813

NATIVE HAWAIIAN LEGAL CORPORATION
1164 BISHOP STREET SUITE 1205
HONOLULU HI 96813

MS CLARA OLDS
SAVE OUR BAYS AND BEACHES
150 HAMAKUA DRIVE SUITE 727
HONOLULU HI 96734

MS PHYLLIS CAYAN
CHAIRPERSON
OAHU BURIAL COMMITTEE
98 295 UALO STREET RM X4
AIEA HI 96701

MR KUNANI NIHIPALI
PRESIDENT
HUI MALAMA I NA KUPUNA O HAWAII NEI
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DIRECTOR WESTERN OFFICE PROJECT REVIEW
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PRESIDENT
NAVY LEAGUE HONOLULU COUNCIL
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OLELO
1122 MAPUNAPUNA STREET
HONOLULU HI 96819

HAWAIIAN ELECTRIC COMPANY
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BISHOP MUSEUM
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TETRA TECH INC
ATTN MS MARY HASSELL
2300 BUENA VISTA SE SUITE 110
ALBUQUERQUE NM 87106

TUNA BOAT OWNERS COOP INC
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HONOLULU HI 96814

MR HAROLD NAGATO *(3 COPIES)*
BEST INDUSTRIES USA INC
851 NANA HONUA STREET
HONOLULU HI 96825-1074

Appendix II-m

Agency Consultation Documents

United States Department of the Interior

FISH AND WILDLIFE SERVICE

PACIFIC ISLANDS ECOREGION
300 ALA MOANA BOULEVARD, ROOM 3108
BOX 50088
HONOLULU, HAWAII 96850
PHONE: (808) 541-3441 FAX: (808) 541-3470

In Reply Refer To: CAW

NOV 18 1997

Mr. Melvin N. Kaku
Director, Environmental Planning Division
Department of the Navy
Pacific Division
Naval Facilities Engineering Command
Pearl Harbor, Hawaii 96850-7300

Re: Informal Consultation Under Section 7 of the Endangered Species Act on the proposed Outfall Replacement for the Wastewater Treatment Plant at Fort Kamehameha, Navy Public Works Center, Pearl Harbor, Hawaii.

Dear Mr. Kaku:

The U.S. Fish and Wildlife Service (Service) has received your October 17, 1997, letter requesting informal consultation under section 7 of the U.S. Endangered Species Act on potential impacts to federally listed species from a proposed outfall at Fort Kamehameha, Navy Public Work Center, Pearl Harbor, Hawaii. The proposed project is to construct a 3.8 kilometer long (2.4 mile long), 105 centimeter diameter (42 inch diameter) outfall pipe, terminating in a 200 meter long (656 foot long) diffuser at a depth of 46 meters (150 feet). The purpose of the project is to relocate the current outfall from within the Pearl Harbor Estuary into open coastal waters. The Service offers the following comments for your consideration.

The Service has reviewed the project location maps included in your letter. We have also reviewed the botanical survey conducted by Dr. Evangeline Funk and the ornithological survey conducted by Phillip L. Bruner. Based on their information, no federally-listed plant species occur within the vicinity of the proposed project site and one federally-listed bird, the Black-necked stilt (*Himantopus mexicanus*), occurs within the proposed project site. The exposed mudflats and sand islets near the project site currently provides foraging habitat for the stilt. However, because of the low numbers and similar undisturbed habitat nearby, the Service will concur with the Navy's determination that the proposed outfall relocation will have no adverse effect on federally-listed species.

Based on this determination, we believe that the requirements of section 7 of the Endangered Species Act (Act) have been satisfied. However, obligations under section 7 of the Act must be reconsidered if (1) new information reveals impacts of the identified action that may affect listed species in a manner which was not previously considered, (2) this action is subsequently modified in a manner which was not considered in this assessment, or (3) a new species is listed or critical habitat determined that may be affected by the action.

We appreciate your concern for endangered species. If you have any questions, please contact our Program Leader for Interagency Cooperation, Ms. Margo Stahl, or Fish and Wildlife Biologist Christine Willis at 808/541-3441.

Sincerely,

For Brooks Harper
Field Supervisor
Ecological Services

cc: NMFS-PAO, Honolulu

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Region
501 West Ocean Boulevard, Suite 4200
Long Beach, California 90802-4213

F/SW033:ETN

DEC - 4 1997

Melvin N, Kaku
Director
Environmental Planning Division
Pacific Division
Naval Facilities Engineering Command
Pearl Harbor, Hawaii 96860-7300

Dear Mr. Kaku:

Thank you for your letter regarding a proposed construction and operation of an outfall for the Wastewater Treatment Plant at Fort Kamehameha, Pearl Harbor, Hawaii. The project is intended to replace the current outfall which discharges into nearshore waters at the entrance to Pearl Harbor. The new outfall will discharge into waters 150 feet deep and 2.4 miles offshore.

Based on a review of the Draft Environmental Impact Statement for the Outfall Replacement for Wastewater Treatment Plant at Fort Kamehameha, Navy Public Works Center, Pearl Harbor, Hawaii, and other available information I concur with your determination that the proposed project is not likely to affect any listed species or designated critical habitat under the jurisdiction of the National Marine Fisheries Service, provided that the following conditions proposed by the Navy are implemented.

1. If listed species are sighted in the project area construction activities will cease and resume only after their departure.

2. The Pacific Islands Protected Species Program will be notified of each such occurrence.

This concludes the informal Section 7 consultation process for this project. Consultation must be reinitiated if new species are listed that may be affected by the proposed activity or the activity affects listed species or critical habitat in a manner or to an extent not previously considered. No incidental takes of listed species are authorized for this project. Please contact me directly at 808/973-2987 should there be any further questions.

Sincerely,

Eugene T. Nitta

Eugene T. Nitta
Protected Species Program
Manager

cc: F/SW023 - Naughton

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
(MAKALAPA, HI)
PEARL HARBOR, HAWAII 96860-7300

5090P.1F3C
Ser 23I7 2180

8 JUN 1998

Dr. Eugene T. Nitta (PSP)
National Marine Fisheries Service, Southwest Region
U.S. Department of Commerce
501 West Ocean Boulevard, Suite 4200
Long Beach, CA 90802-4213

Dear Dr. Nitta:

Subj: DRAFT ENVIRONMENTAL IMPACT STATEMENT DEIS) REVIEW AND INFORMAL SECTION 7 CONSULTATION FOR OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR, HAWAII

Thank you for your letter of December 4, 1997, on the DEIS review and informal Section 7 consultation for the above proposed action. We understand that the National Marine Fisheries Service (NMFS) concurs with the determination that the proposed project is not likely to affect any listed species or designated critical habitat under the jurisdiction of the NMFS, provided the conditions proposed in the DEIS are followed. We also understand that the Section 7 consultation must be reinitiated if new species are listed that may be affected by the proposed action or if the action affects listed species or critical habitat in a manner or to an extent not previously considered. In addition, we acknowledge the fact that no incidental takes of listed species are authorized for this project.

Should you have any questions, please contact Mr. Gary Kasaoka (Code 231GK) at (808) 471-9338 or by facsimile transmission at (808) 474-5909.

Sincerely,

Melvin N. Kaku
MELVIN N. KAKU
Director
Environmental Planning Division

Copy to:
Belt Collins Hawaii
680 Ala Moana Boulevard, First Floor
Honolulu, HI 96813

BENJAMIN J. CAYETANO
GOVERNOR OF HAWAII

STATE OF HAWAII

DEPARTMENT OF LAND AND NATURAL RESOURCES

STATE HISTORIC PRESERVATION DIVISION
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MICHAEL D. WILSON, CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES

DEPUTIES

GILBERT COLOMA-AGARAN

AQUACULTURE DEVELOPMENT PROGRAM
AQUATIC RESOURCES
CONSERVATION AND RESOURCES ENFORCEMENT
CONVEYANCES
FORESTRY AND WILDLIFE
HISTORIC PRESERVATION DIVISION
LAND DIVISION
STATE PARKS
WATER AND LAND DEVELOPMENT

REF: HP-JEN

JAN -6 1998

LOG NO: 20737
DOC NO: 9712SC06

Mr. Melvin N. Kaku, Director
Environmental Planning Division
Department of the Navy, Pacific Division
Naval Facilities Engineering Command
Pearl Harbor, Hawaii 96860-7300

Dear Mr. Kaku:

SUBJECT: **National Historic Preservation Act, Section 106 Compliance - Outfall Replacement for Wastewater Treatment Plant (WWTP) At Fort Kamehameha, Navy Public Works Center**
Pearl Harbor, Halawa, ʻEwa District, Oʻahu
TMK: 9-9-001

Thank you for the opportunity to review and comment on the proposed outfall replacement for the Fort Kamehameha wastewater treatment plant at Fort Kamehameha, Oʻahu. Our review is based on historic reports, maps, and aerial photographs maintained at the State Historic Preservation Division. In addition, Sara Collins and Elaine Jourdane of my staff made a brief visit of the general project area in November 1997, in the company of Hickam Air Force Base personnel. Finally, Ms. Annie Griffin of your office provide us with two draft archeological reports for informational purposes, to assist us in this review (*Preliminary Report. Phase IV: Archaeological Monitoring, Testing, and Emergency Data Recovery at Fort Kamehameha Wastewater Treatment Plant Pearl Harbor, Hawaiʻi.* 1996. Drolet; *Prefinal Report. Phase II Archaeological Subsurface Testing and Data Recovery, Wastewater Treatment Plant at Fort Kamehameha, Pearl Harbor, Oʻahu, Hawaiʻi.* Vol. 1. 1997. Drolet et al.).

According to your information, the underwater portion of the proposed undertaking will be carried out within the existing channel, which has been dredged periodically over the decades; none of the WW II-era aircraft or shipwrecks are known to be in the vicinity of the proposed outfall. The construction parcels adjacent to the project site are either paved over or have undergone subsurface testing with no significant historic sites found. In view of these facts, we concur with the determination in the DEIS that the proposed undertaking will have "no effect" on significant historic sites.

Per your request, we are returning the two draft reports you provided us for informational purposes; we understand that you will eventually forward copies to us for review, and we look forward to receiving them.

Should you have any questions, please feel free to call Sara Collins at 587-0013.

Aloha,

Gilbert Coloma-Agaran
for Michael D. Wilson, Chairperson, and
State Historic Preservation Officer

DEPARTMENT OF BUSINESS, ECONOMIC DEVELOPMENT & TOURISM

OFFICE OF PLANNING
235 South Beretania Street, 6th Flr., Honolulu, Hawaii 96813
Mailing Address: P.O. Box 2359, Honolulu, Hawaii 96804

BENJAMIN J. CAYETANO
GOVERNOR
SEIJI F. NAYA
DIRECTOR
BRADLEY J. MOSSMAN
DEPUTY DIRECTOR
RICK EGGED
DIRECTOR, OFFICE OF PLANNING

Tel.: (808) 587-2846
Fax: (808) 587-2824

Ref. No. P-7193

February 5, 1998

Mr. Melvin N. Kaku
Director
Environmental Planning Division
Department of the Navy
Pacific Division
Naval Facilities Engineering Command
Pearl Harbor, Hawaii 96860-7300

Dear Mr. Kaku:

Subject: Hawaii Coastal Zone Management (CZM) Program Federal Consistency for the Proposed Outfall Replacement for the Fort Kamehameha Wastewater Treatment Plant

Your proposal to construct a deep ocean effluent outfall for the Fort Kamehameha Wastewater Treatment Plant that will discharge into the open coastal waters outside of the Pearl Harbor entrance channel has been reviewed for consistency with Hawaii's CZM Program. It is our understanding that a Water Quality Certification under Section 401 of the Clean Water Act and a National Pollutant Discharge Elimination System (NPDES) Permit are required for the outfall construction and wastewater discharge. We do not object to the proposed Federal activity provided that the following conditions are applied.

1. Approval is obtained from the Department of Land and Natural Resources for constructing the outfall on State-owned submerged lands.

2. The outfall construction and effluent discharge shall be in compliance with State water quality standards and requirements of the Department of Health.

This CZM consistency review is not an endorsement of the project nor does it convey approval with any other regulations administered by any State or County agency. Thank you for your cooperation in complying with Hawaii's CZM Program. If you have any questions, please call John Nakagawa of our CZM Program at 587-2878.

Sincerely,

Rick Egged
Director
Office of Planning

cc: U.S. Army Corps of Engineers, Operations Branch
U.S. National Marine Fisheries Service, Pacific Area Office
U.S. Fish and Wildlife Service, Pacific Islands Ecoregion
Department of Health, Clean Water Branch
Department of Land & Natural Resources, Planning & Technical Services Branch
Department of Land Utilization, City & County of Honolulu

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
(MAKALAPA, HI)
PEARL HARBOR, HAWAII 96860-7300

5090P.1F3C
Ser 231/2334
19 JUN 1998

Mr. Rick Egged, Director of Planning
Department of Business, Economic
Development and Tourism
P.O. Box 2359
Honolulu, HI 96804

Dear Mr. Egged:

Subj: COASTAL ZONE MANAGEMENT CONSISTENCY DETERMINATION FOR PROPOSED OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER (PWC), PEARL HARBOR

Thank you for your letter of February 5, 1998 (DBEDT/OP Ref. No. 7193) on the Hawaii Coastal Zone Management Program Federal Consistency for the above action in which you stated that your agency has no objections to the proposed project provided that: (1) approval is obtained from the Department of Land and Natural Resources for constructing the outfall on State-owned submerged lands, and (2) the outfall construction and effluent discharge shall be in compliance with State water quality standards and requirements of the Department of Health (DOH).

First, in the event that the outfall alignment that is selected will require construction on submerged lands, such construction will be conducted wholly on federally owned submerged lands. Thus approval from the Department of Land and Natural Resources will not be needed.

On the second condition, the Navy will be obtaining a Section 401 Water Quality Certification from the DOH Clean Water Branch in conjunction with a Department of the Army permit under Section 404 of the Clean Water Act for the construction phase of the project. Prior to the completion of this project, PWC Pearl Harbor, the operator of the treatment plant, will be obtaining a modification of its existing wastewater discharge National Pollutant Discharge Elimination System permit under Section 402 of the same act.

Should you have any questions, please contact Mr. Gary Kasaoka (Code 231GK) at 471-9338 or by facsimile transmission at 474-5909.

Sincerely,

Melvin N. Kaku
MELVIN N. KAKU
Director
Environmental Planning Division

Copy to: (See next page)

5090P.1F3C
Ser 231/2334

Copy to:
U.S. Army Corps of Engineers
Attn: Operations Branch (CEPOD ET PO)
Building 230
Fort Shafter, HI 96858-5440

Mr. John Naughton
National Marine Fisheries Service
Pacific Area Office
2570 Dole Street
Honolulu, HI 96822-2396

Mr. Brooks Harper
U.S. Fish and Wildlife Service
300 Ala Moana Boulevard, Room 3108
Box 50088
Honolulu, HI 96850

Mr. Dennis Lau
Department of Health
Clean Water Branch
919 Ala Moana Boulevard, Room 300
Honolulu, HI 96814

Department of Land and Natural Resources
Planning and Technical Services Branch
P.O. Box 621
Honolulu, HI 96809

Department of Land Utilization
City and County of Honolulu
650 South King Street
Honolulu, HI 96813

Belt Collins Hawaii
680 Ala Moana Boulevard, First Floor
Honolulu, HI 96813

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
LAND DIVISION
PO BOX 621
HONOLULU, HAWAII 96809

JUL - 7 1998

Ref.:PB:SL

Mr. Melvin N. Kaku, Director
Environmental Planning Division
Department of the Navy
Naval Facilities Engineering Command
Pearl Harbor, Hawaii 96860-7300

Dear Mr. Kaku:

Subject: Outfall Replacement for the Fort Kamehameha, Navy Public Works Center (PWC), Pearl Harbor, Hawaii

We are in receipt of a letter from you to Mr. Rick Egged of the Department of Business, Economic Development and Tourism in which you discuss the construction of the subject outfall on federally owned submerged land. We would be interested in receiving any documentation, including maps, establishing federal ownership of the subject lands with respect to the project area, prior to a determination that our approval will not be required.

Thank you for your cooperation in this matter. Please feel to call Sam Lemmo of the Planning Branch, at 587-0381, should you have any questions on this matter.

Aloha,

Dean Y. Uchida, Administrator
Land Division

cc: Chairman's Office
Linnel Nishioka
Rick Egged

SUB ENCLOSURE (/).

---

23 —
231 Ex c/c
231 GK [illegible]

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
LAND DIVISION
P.O. BOX 621
HONOLULU, HAWAII 96809

AUG - 3 1998

Ref:PB:THE

File: Cor98.107

Melvin N. Kaku, Director
Environmental Planning Division
Naval Facilities Engineering Command
Pacific Division
Department of the Navy
Pearl Harbor, Hawaii 96860-7300

Dear Mr. Kaku,

SUBJECT: Proposed Outfall Replacement for Wastewater Treatment Plant at Fort Kamehameha

We received our copy of your letter (dated 19 June 1998) to the State Office of Planning regarding the Coastal Zone Management Consistency Determination for the subject outfall, and we have the following comments.

Your letter indicates that approval from our department would not be needed in the event that the selected outfall alignment requires construction on submerged lands, since such construction would be conducted wholly on federally-owned submerged lands. Should such an outfall alignment be selected, we wish to be informed of its specific location, along with an identification of the referenced federally-owned submerged lands. Such information will assist in our statutory natural resource planning functions.

Thank you in advance for your assistance with this matter. Should you have any questions, please feel free to contact Tom Eisen of our Planning Branch at 587-0386.

Sincerely,

Dean Y. Uchida, Administrator
Land Division

cc: Oahu Board member
CZM

ENCLOSURE (/)

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
(MAKALAPA, HI)
PEARL HARBOR, HAWAII 96860-7300

5090P.1F3C
Ser 231/ 3148

26 AUG 1998

Mr. Dean Y. Uchida, Administrator
Land Division
Hawaii Department of Land and Natural Resources
P.O. Box 621
Honolulu, HI 96809

Dear Mr. Uchida:

Subj: PROPOSED OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT AT FORT KAMEHAMEHA, NAVY PUBLIC WORKS CENTER, PEARL HARBOR

Thank you for your letters of July 7, 1998 (Ref.:PB:SL) and August 3, 1998 (Ref.:PB:THE) in which you commented on the Navy's response to the Hawaii Coastal Zone Management Program regarding the Federal Consistency consultation of subject project. Specifically, you questioned the Navy's claim that approval from the Hawaii Department of Land and Natural Resources for constructing the outfall would not be needed because all in-water work for the project would be conducted on federally owned submerged lands. You asked that we provide the State with documentation, including maps, establishing federal ownership of the submerged lands in question. You also requested to receive the specific location of the outfall after the alignment is chosen in order to assist your agency in its statutory natural resource planning functions.

The Navy's title to the lands in question derives from Presidential Executive Order No. 8143, issued on May 26, 1939, which established Pearl Harbor as a Defensive Sea Area and operated to set aside the land and water within the boundaries specified in the order for the use of the United States. At statehood, by virtue of Section 5(c) of the Hawaii Admission Act, title of these set-aside lands remained in the United States. Enclosures (1) and (2) are forwarded for your information.

A soft-soil condition along the original outfall alignment discovered subsequent to issuing the Draft Environmental Impact Statement (EIS) has required additional engineering fieldwork to circumvent the problem area. Consequently, the exact alignment for the outfall is not available at this time, but we do expect to have what you need to accomplish your planning functions in the Final EIS, which is scheduled to be distributed for review in February 1999. In any case, the proposed outfall replacement will be built wholly within the Pearl Harbor Defensive Sea Area.

Should you have any questions, please contact Mr. Gary Kasaoka (Code 231GK) at 471-9338 or by facsimile transmission at 474-5909.

Sincerely,

Stanley Y. Uehara
STANLEY Y. UEHARA
Director
Environmental Planning Division
Acting

Encl:
(1) Executive Order No. 8143
(2) Pearl Harbor Defensive Sea Area Drawing

Copy to:
Mr. Rick Egged, Director of Planning
Department of Business, Economic
Development and Tourism
P.O. Box 2359
Honolulu, HI 96804

U.S. Army Corps of Engineers
Attn: Operations Branch (CEPOD ET PO)
Building 230
Fort Shafter, HI 96858-5440

Mr. John Naughton
National Marine Fisheries Service
Pacific Area Office
2570 Dole Street
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Ms. Karen Rosa, Acting Field Supervisor
U.S. Fish and Wildlife Service
300 Ala Moana Boulevard, Room 3108
Box 50088
Honolulu, HI 96850

5090P.1F3C
Ser 231/ 3148

Mr. Dennis Lau
Hawaii Department of Health
Clean Water Branch
919 Ala Moana Boulevard, Room 300
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Ms. Jan Sullivan, Director
Department of Planning and Permitting
City and County of Honolulu
650 South King Street
Honolulu, HI 96813

Blind copy to:
Mr. Calvin Tsuda
SSFM Engineers, Inc.
502 Sumner Street, Suite 502
Honolulu, HI 96817

Mr. Walter Billingsley
Belt Collins Hawaii
680 Ala Moana Boulevard, First Floor
Honolulu, HI 96813

COMNAVBASE Pearl Harbor (N422)
PWC Pearl Harbor (Codes 09SC, 09B)

09C
241
5016

"Executive Order Establishing a Defensive Sea Area in and About Pearl Harbor, Hawaii

"By virtue of and pursuant to the authority vested in me by the provisions of section 44 of the Criminal Code, as amended (U. S. C., title 18, sec. 96), the area of water in Pearl Harbor, Island of Oahu, Territory of Hawaii, lying between extreme high-water mark and the sea in and about the entrance channel to said harbor, within an area bounded by the extreme high-water mark, a line bearing south true from the southwestern corner of the Puuloa Naval Reservation, a line bearing south true from Ahua Point Lighthouse, and a line bearing west true from a point three nautical miles due south true from Ahua Point Lighthouse, is hereby established as a defensive sea area for purposes of national defense.

"At no time shall any person (other than persons on public vessels of the United States) enter the defensive sea area above defined, nor shall any vessels or other craft (other than public vessels of the United States) be navigated within said defensive sea area, unless authorized by the Secretary of the Navy.

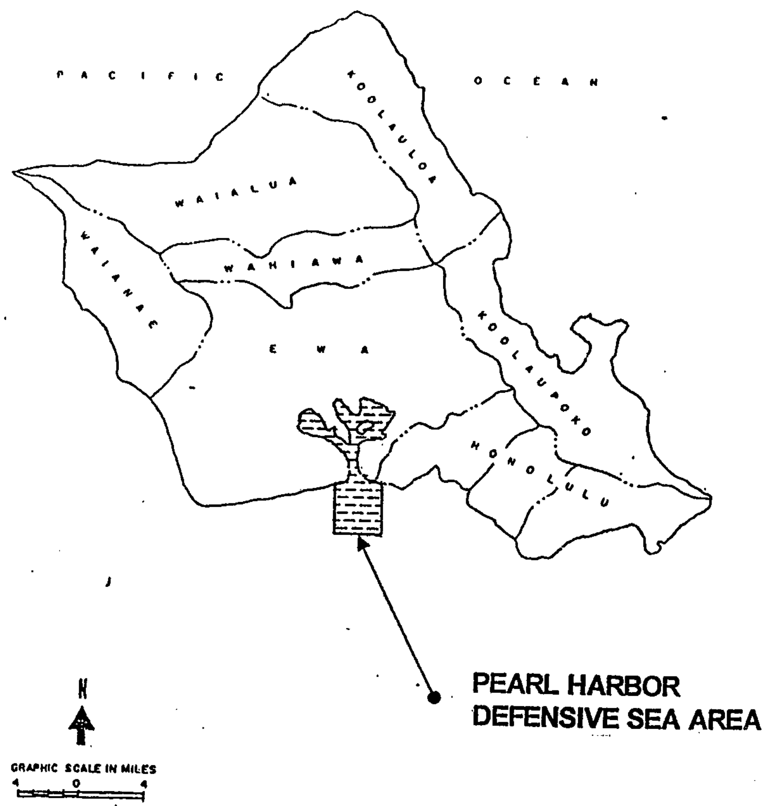
"Any person violating the provisions of this order shall be subject to the penalties provided by law.

"FRANKLIN D. ROOSEVELT.

"THE WHITE HOUSE,
May 26, 1939."

(No. 8143)

ENCLOSURE (/)



ISLAND OF OAHU

ENCLOSURE (2)

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
(MAKALAPA, HI)
PEARL HARBOR, HAWAII 96860-7300

5090P.1F3C
Ser PLN231/3988

10 NOV 1999

Mr. Alan Everson
Pacific Islands Area Office
National Marine Fisheries Service, SW Region
1601 Kapiolani Blvd., Suite 1110
Honolulu, HI 96814-4700

Dear Mr. Everson:

The purpose of this letter is to initiate an Essential Fish Habitat (EFH) consultation under Section 305(b) of the Magnuson-Stevens Act (16 U.S.C. 1855(b)) for the proposed Wastewater Treatment Plant (WWTP) at Fort Kamehameha Outfall Replacement project (MCON P-497). Pertinent information on the project and reconnaissance dives is enclosed.

The U.S. Navy is in the late stages of preparing a Final Environmental Impact Statement (FEIS) for the construction and operation of a replacement sewer outfall at the Wastewater Treatment Plant at Fort Kamehameha. Work on the EIS began in the fall of 1996. The FEIS is scheduled for public review and comment in February 2000. A copy of the FEIS will be provided to your offices for review at that time. However, we respectively request that your response to this consultation is kept separate and distinct from any comments you might wish to make on the FEIS following your review.

Should you have any questions on the project, please contact Mr. Gary Kasaoka (PLN231GK) at 471-9338 or by facsimile transmission at 474-5909. Technical questions on the fieldwork should be directed to Mr. Stephen Smith (PLN232SS) at 474-5922.

Sincerely,

Melvin N. Kaku
MELVIN N. KAKU
Director
Environmental Planning Division

Encl:
(1) MCON P-497 Project Summary and EFH Narrative
(2) Aerial Photograph of Proposed Alignment
(3) Overall General Plan

Copy to: (w/o encl)
David W. Blane, Director
Office of Planning – CZM Program
Dept. of Business, Economic Development, and Tourism
P.O. Box 2359
Honolulu, HI 96804

SSFM Engineers, Inc.
501 Sumner St., Suite 502
Honolulu, HI 96817

PLN231/99C026-10-14
9 November 1999

OUTFALL REPLACEMENT FOR WASTEWATER TREATMENT PLANT (WWTP) AT FORT KAMEHAMEHA (MCON P-497) NAVY PUBLIC WORKS CENTER, PEARL HARBOR

The proposed action is to construct a 3.9-kilometer (2.4-mile)-long, 107-centimeter (42-inch)-diameter outfall pipe that would terminate in a 200-meter (656-foot)-long diffuser at a depth of 46 meters (150 feet). The outfall will extend into the Class A open coastal waters of Mamala Bay outside the entrance channel to Pearl Harbor.

Three construction methods will be used to construct the outfall, as follows: (1) Open Trenching; (2) Microtunneling; and (3) Pile-supported Piping. Open trenching is the method of choice for the reef flat and a segment running along the base of the channel wall between the microtunneling segment and the pile-supported distal portion of the outfall alignment. The middle portion of the alignment will be microtunneled to effectively avoid impacting an area with a relatively large established community of living corals. This segment of the outfall will resurface at the base of the incline at the eastern side of the entrance channel and proceed seaward through an open-trench constructed segment. At the steeper sandy section of the alignment, from the 20-m (66-ft) to the 46-m (150-ft) depths, the pipeline will be secured to underlying pile caps and tie-beams to stabilize and support the outfall just above the surface of the sea floor. The diffuser at the distal end of the outfall will also be constructed in this manner.

With the varied substrate and ecological conditions, there is the potential to impact Essential Fish Habitat (EFH) of those species with Fishery Management Plans (FMPs) under the Magnuson-Stevens Act. The impacts of constructing the proposed replacement outfall on Habitat Areas of Particular Concern (HAPC) are discussed below.

The Western Pacific Regional Fishery Management Council (WPRFMC) currently has adopted amendments to four FMPs. The amendments are intended to address the Essential Fish Habitat provisions of the Magnuson-Stevens Act. They are as follows:

a. Amendment 10 to the Crustaceans FMP
b. Amendment 4 to the Precious Corals FMP
c. Amendment 8 to the Pelagic Fisheries FMP
d. Amendment 6 to the Bottomfish and Seamount Groundfish FMP

Discussions were held with NMFS personnel on September 30, 1999 to assess potential project impacts to the EFHs delineated in these amendments. The NMFS personnel stated that they were concerned only with potential conflicts with the Bottomfish and Seamount Groundfish FMP. Specifically, NMFS personnel requested that an assessment be completed for the Habitat of Particular Concern (HAPC). The proposed project does not traverse HAPCs for any of the other FMPs listed above. The HAPC for bottomfish includes areas between 40 and 280-m depth that support ledges, escarpments and/or steeply sloping hard bottom areas. The diffuser portion of the WWTP outfall pipeline was suspected of being within this HAPC.

It was agreed that the Navy would review recently completed biological and geophysical survey data covering the diffuser portion of the alignment. Furthermore, one or more dives would be conducted, to obtain direct, current observational data. Four documents and a videotape of the underwater alignment were carefully reviewed. The documents are as follows:

a. Pre-Final Iteration Final Environmental Impact Statement Outfall Replacement for Wastewater Treatment Plant at Fort Kamehameha, Navy Public Works Center, Pearl Harbor, Hawaii (October 1998)

b. Geotechnical Investigation Report Ocean Outfall Extension Wastewater Treatment Plant at Fort Kamehameha, Pearl Harbor, Oahu, Hawaii (URS Greiner Woodward Clyde, January 1999)

c. Assessment of Water Quality and Marine Community Structure Fort Kamehameha Ocean Outfall Extension Oceanographic Study (Marine Research Consultants, February, 1996)

d. An Assessment of Biological Communities in the Vicinity of the Proposed Fort Kamehameha Sewer Outfall (Marine Research Consultants, April 1997).

Two scuba dives were made along the diffuser segment on October 14, 1999. The first dive was conducted at location 3 X 900, the second at 3 X 750. Portions of the EOD survey line could be seen at the first survey site and familiar metallic debris, as recorded in the underwater video previously taken. Underwater visibility during each of the dives was in excess of 75 feet, so it was easy to obtain a clear view of the corridor and the adjacent areas.

Based upon all of the above sources of information, it can be confidently stated that there are no ledges, escarpments or steeply sloping hard bottom segments at any point below 40 meters along the proposed outfall corridor. The portion of the project below 40 meters is a very gently sloping to flat, featureless, sand bottom, with small-scattered sections of rubble. One small boulder (approximately 0.6m in diameter) was sighted. Fishes observed during the October 14, 1999 dives were limited to one school of approximately 40 goatfish (tentatively yellowfin goatfish *Mulloidichthys pflugeri*), milletseed butterflyfish (*Chaetodon milaris*), Hawaiian domino damselfish (*Dascyllus albisella*) and orangeband surgeonfish (*Acanthurus olivaceous*). Except for the goatfish, all the fishes were observed adjacent to metallic debris.

In sum, it is our belief that there is no HAPC at any point along the proposed outfall alignment. We would appreciate an acknowledgement of your concurrence with our conclusions.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Region
Pacific Islands Area Office
1601 Kapiolani Boulevard, Suite 1110
Honolulu, Hawaii 96814-0047

NOV 19 1999

Mr. Melvin N. Kaku
Director, Environmental Planning Division
Department of the Navy
Naval Facilities Engineering Command
Pearl Harbor, Hawaii 96860-7300

Dear Mr. Kaku:

The National Marine Fisheries Service (NMFS) has reviewed the Essential Fish Habitat (EFH) Assessment prepared for the proposed Wastewater Treatment Plant (WWTP) at Fort Kamehameha, Pearl Harbor Outfall Replacement project. The document was prepared by the Environmental Planning Division to initiate early EFH consultation under Section 305(b) of the Magnuson-Stevens Act (16 U.S.C. 1855(b). Based on preliminary discussion with the Navy and review of various draft environmental documents, it has been determined that the preferred outfall alignment traverses areas identified as EFH under the following Fisheries Management Plans (FMP):

- Bottomfish and Seamount Groundfish
- Pelagic
- Crustaceans

It has also been determined that the diffuser portion of the WWTP outfall pipe falls within the depth range (46 meters) of a Habitat Area of Particular Concern (HAPC) for Bottomfish. This HAPC includes all escarpments/slopes between 40 and 280 m depth.

The proposed project design includes adequate measures to insure minimal impacts to EFH for species managed under these FMPs. These measures include minimizing impacts from open trench areas by avoiding live coral habitat, the use of microtunneling to further avoid impacts to habitat, and the use of pile supports for the distal portion (diffuser section) of the outfall alignment. Based on the information provided in various supporting documents and additional information obtained during reconnaissance dives at the diffuser site, it appears unlikely that the installation of the diffuser will adversely impact the HAPC for bottomfish.

An additional EFH assessment may be required once the final Environmental Impact Statement is completed and the preferred alignment is selected. This assessment should be prepared by the Corps of Engineers during the Department of the Army permit process. At that time, further EFH Conservation Recommendations may be necessary.

Thank you for your consideration. Should you have any questions, please contact John Naughton at 973-2935, extension 211 or Alan Everson at 973-2935, extension 212.

Sincerely,

C. Karnella

Charles Karnella
Administrator
Pacific Islands Area Office

Copies Furnished:

Mr. James Slawson, Southwest Region, NMFS, 501 West Ocean Blvd., Suite 4200, Long Beach, CA 90802-4213
Mr. Mark Minton, Western Pacific Fishery Management Council, 1164 Bishop Street, Suite 1400, Honolulu, HI 96813
Hawaii State Department of Business, Economic Development and Tourism, Office of Planning, Coastal Zone Management Program, P.O. Box 2359, Honolulu, HI 96804

Appendix III

Feasibility of Wastewater Disposal Wells for the Fort Kamehameha WWTP at Pearl Harbor, Hawaii

TNWRE
Tom Nance Water
Resource Engineering

February 27, 1997
97TN-068 (97-16)

Mr. Fred Heyler
Belt Collins Hawaii
680 Ala Moana Boulevard - 1st Floor
Honolulu, Hawaii 96813

Dear Fred:

Feasibility of Wastewater Disposal Wells For the
Fort Kamehameha WWTP at Pearl Harbor, Oahu

This brief letter report provides a preliminary evaluation of the feasibility of developing wells at the Fort Kamehameha Wastewater Treatment Plant (WWTP) to dispose of up to 1150 liters per second (lps). The evaluation is based on available published information, logs of test borings at the WWTP site, and the author's experience. The WWTP is located along the east side of the entrance channel into Pearl Harbor (refer to Figure 1). Ground elevations across the site vary from 1.2 to 3.6 meters above mean sea level.

Hydro-Geologic Circumstance

The WWTP lies on a coastal formation comprised of layers of coral and coralline sands and gravels interspersed with layers of silt and clay. These sedimentary layers are often referred to as "caprock" as they provide a cap to the underlying volcanics. Based on the boring logs of deep wells located on both sides of the entrance channel to Pearl Harbor, the sedimentary layers are likely to have a combined thickness of about 300 meters beneath the WWTP site (Figure 2).

Permeability of the calcareous layers of the caprock is extremely variable. In the karstic reef limestone, permeability coefficients can be 7 cm/sec and higher. In contrast, in areas of lagoonal deposition, the permeability of calcareous material can be as low as 10^{-3} cm/sec. The intervening mud layers have permeabilities of about 10^{-4} cm/sec. They generally function as aquicludes, hydraulically separating the coral layers above and below the mud. Permeability of the volcanics at depth, if they are comprised of typical basalt flows, are likely to be in the range of 0.3 to 2 cm/sec.

On the Ewa Plain to the west of Pearl Harbor's entrance channel, the uppermost limestone layer contains brackish groundwater in a basal lens. It is a significant source of irrigation supply for golf courses and landscape irrigation. Since similar exploitation of groundwater in the uppermost coral layer on the east side of the entrance channel has not occurred, very little is known of groundwater conditions or the hydraulic properties of the formation there.

On the west side of the Ewa Plain, the second limestone layer is used wastewater disposal by several cogeneration power plants. Injection rates vary from 30 to more than 200 lps per well. Again, no exploitation or use of the second limestone layer on the east side of Pearl Harbor's entrance channel has ever been attempted.

Disposal Well Options

There are three different strata to consider as the receiving formation for wastewater disposal: the upper limestone layer; the second (or lower) limestone layers; and the volcanics at depth. Tables 1 and 2 provide compilations of the depth and thickness of these layers based on the available boring logs of deep wells. The layers can be characterized as follows:

1. The upper limestone layer is likely to be 60 to 75 meters thick beneath the WWTP site. The onsite borings, although limited in depth, indicate that clean limestone begins on the order of 15 meters below sea level. The advantages of using this stratum for disposal are its likely high permeability and the relatively moderate well depths that would be required. The disadvantage is the possible emergence of effluent in the ocean in relatively shallow water offshore.

2. Based on the well logs, the second (and lower) limestone layers are substantially thinner than the uppermost layer. There is also virtually no data of other indications of the permeability of these layers. The advantage of using the lower layers as the receiving formation is that overlying mud layers would ensure emergence of the effluent in the ocean environment further offshore. The primary disadvantages are added well costs, questionable permeability, and the limited thickness of the layers. Wells delivering water to these depths are likely to have substantially less capacity than wells into the uppermost layer.

3. The top of the unweathered volcanics is at least 300 meters below ground at the WWTP site. If the volcanic formation is used for disposal, it would require very deep and expensive wells. Although water in the volcanics would be brackish to saline and there are no drinking water wells in this formation for several kilometers inland, its use for disposal would still be given close scrutiny. Another disadvantage is that the piezometric head of this formation is likely to be above ground. The flowing wells would have to be capped and it would be necessary to force water into the formation by pumping.

Recommendations

1. Given the very high required disposal rates, prospective well capacities in the formations described above, and the cost of wells to the required depths, use of the upper limestone layer for disposal is the preferred choice. Since most of the onsite borings show silts and clays to depths of 10 to 15 meters, their low permeability should make emergence of effluent near the shoreline less likely.

2. To evaluate disposal feasibility, the next step should be to develop a prototype well. It would provide data on formation thickness, permeability, and prospective well capacities.

3. If the limestone layer is determined to extend to a depth of at least 75 meters, solid casing should be installed to a depth of 30 meters. Subject to non-caving conditions, the remainder of the well's 75-meter depth should be left as open hole. A well screen should only be used if a caving formation is encountered. In anticipation of a well capacity of up to 200 lps, use 35-cm, Schedule 80, PVC casing for the prototype.

Mr. Fred Heyler
February 27, 1997 -- 97TN-068
Page three

4. The annulus outside the solid casing should be filled with grout. However, sounding tubes with open intervals from 30 to 40 and from 60 to 70 feet should also be installed in the annulus so that the hydraulic response in the upper part of the formation can be monitored during pump and injection testing.

5. To develop sufficient hydrologic data to support the viability of a field of disposal wells, a small diameter monitor well (or nest of monitor wells) should be installed in conjunction with the prototype well. These should be open to the formation at the same depths as the prototype and its annular sounding tubes: 30 to 40 feet; 60 to 70 feet; and 100 feet to the bottom of the coral layer. The well should be located about 50 feet seaward of the prototype well.

6. The static water level in the well is likely to be about a foot above the mean ocean level and vary with the tide. If the available gravity head is on the order of 10 feet and permeabilities of the limestone are similar to wells on the west side of the channel entrance, capacities up to 3000 GPM per well might be achievable. This would mean a minimum of seven wells (one as standby) to accommodate 18,000 GPM.

7. The location of the disposal wells within the WWTP site or on adjacent land should be based on operational and delivery piping considerations. Within the relatively small area of the WWTP and its surroundings, there is no hyrologic basis to favor one side of the site over another. If a field of disposal wells is to be developed, a tentative spacing of 100 feet with the wells arrayed parallel to the shoreline would be appropriate.

I am available to discuss the contents of this letter or to discuss other groundwater disposal options at your convenience.

Sincerely,

Tom Nance

Tom Nance

Enclosures

Table 1

Coral Layers Delineated By Deep Wells on the East Side of the Channel Into Pearl Harbor

State Well No.	2055-02	2056-03	2056-01	2057-02	2056-02	2057-03	2057-01	2157-02
Old Well No.	162	163	164	165	166	167	168	170
Distance From the Fort Kamehameha WWTP (Feet)	13,700	12,100	7,300	7,250	8,000	8,000	8,000	9,400
Ground Elevation (Ft. MSL)	20	17	12	2	15	15	15	18
Upper Coral Layer								
• Elevations (Top/Bottom in Ft. MSL)	+20/-220	+17/-233	+12/-233	+2/-221	+12/-218	-19/-235	+13/-192	+18/-82
• Thickness (Feet)	240	250	245	223	230	216	205	100
Second Coral Layer								
• Elevations (Top/Bottom in Ft. MSL)	-295/-320	-273/-303	-278/-308	-291/-321	-233/-298	-388/-418	-257/-287	-112/-132
• Thickness (Feet)	35	30	30	30	65	30	30	20
Other Coral Layers								
• Number of Layers	6	2	3	2	4	None	2	1
• Average Thickness	20	20	37	16	30	--	28	21
Underlying Volcanics								
• Elevation at Top of Unweathered Volcanics (Ft. MSL)	-1,000	-800	-755	-825	-875	-940	-850	-560
• Chloride Concentration (MG/L)	Not Avail.	1,600	1,700	3,800	1,600	Not Avail.	2,000	2,200

Note: Information from Stearns and Vaksvik (1938).

Table 2

Coral Layers Delineated By Deep Wells on the West Side of the Channel Into Pearl Harbor

State Well No.	2100-02	2059-01	1959-05
Old Well No.	T-134	272	T-133
Distance From the Fort Kamehameha WWTP (Feet)	15,700	11,250	11,100
Ground Elevation (Ft. MSL)	21	16	4
Upper Coral Layer			
• Elevations (Top/Bottom in Ft. MSL)	-4/-76	+16/-149	+4/-202
• Thickness (Feet)	72	165	206
Second Coral Layer			
• Elevations (Top/Bottom in Ft. MSL)	-129/-144	-289/-344	-243/-263
• Thickness (Feet)	15	55	20
Other Coral Layers			
• Number of Layers	2	5	3
• Average Thickness	13	28	72
Underlying Volcanics			
• Elevation at Top of Unweathered Volcanics (Ft. MSL)	-535	-770	-1,070
• Chloride Concentration (MG/L)	Not Avail.	6,600	17,600

Note: Information from Stearns and Vaksvik (1938), Cox and Lao (1967), and Resig (1969).

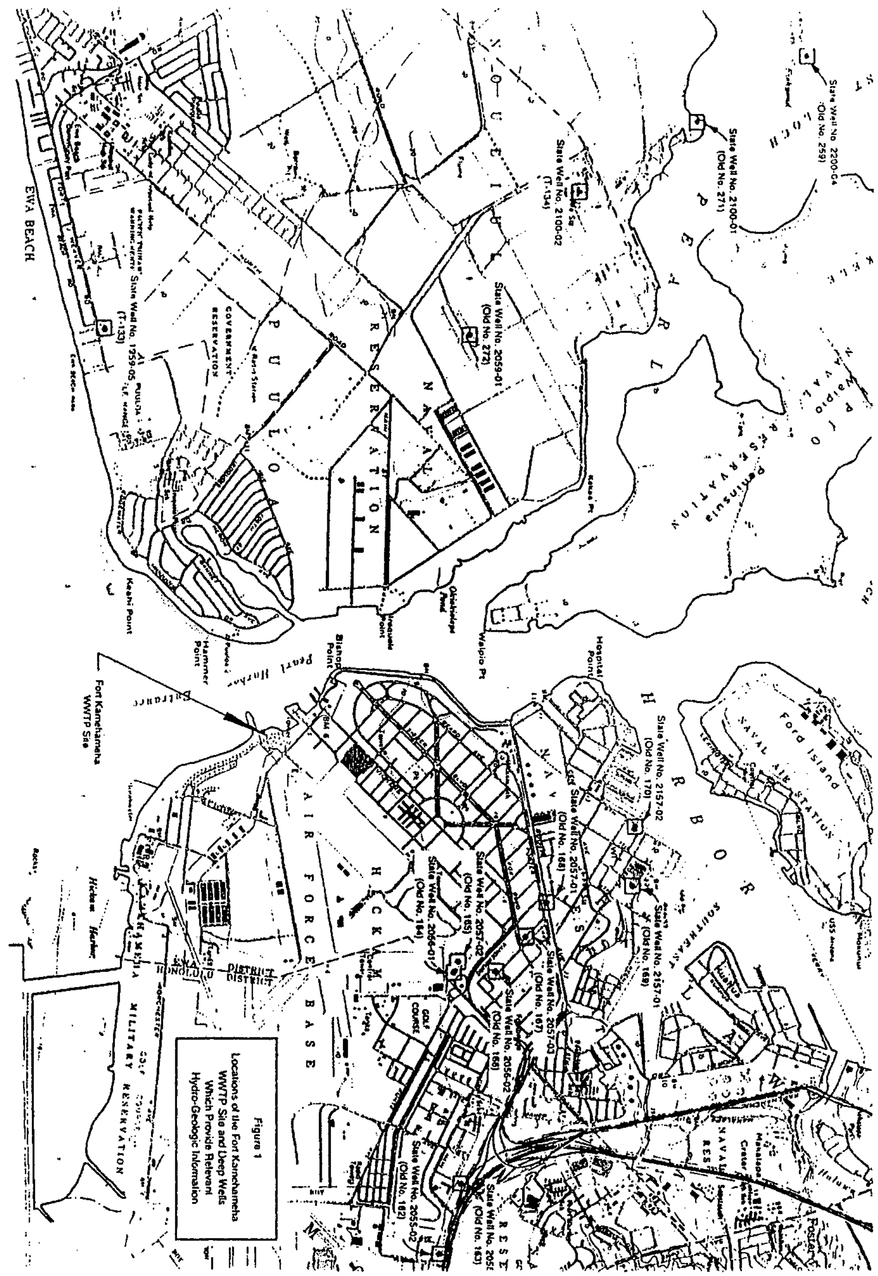


Figure 1
Locations of the Fort Kamehameha WWTP Site and Deep Wells Which Provide Relevant Hydro-Geologic Information

References With Relevant Information on Hydro-Geologic Conditions

Cox, D.C. and C. Lao. 1967. Development of Deep Monitoring Stations in the Pearl Harbor Ground Water Area, Oahu. Technical Report No. 4, OWRR Project No. A-011-HI. Water Resources Research Center, University of Hawaii.

George A.L. Yuen & Associates. 1989. Groundwater Resources and Sustainable Yield of the Ewa Plain Caprock Aquifer. Report R-79, Commission on Water Resource Management, DLNR, State of Hawaii.

Hawaii Geotechnical Group. 1992. FY93 MCON Project P-483, Expand Wastewater Treatment Plant, Fort Kamehameha, Pearl Harbor, Hawaii. Consultant report prepared for M&E Pacific.

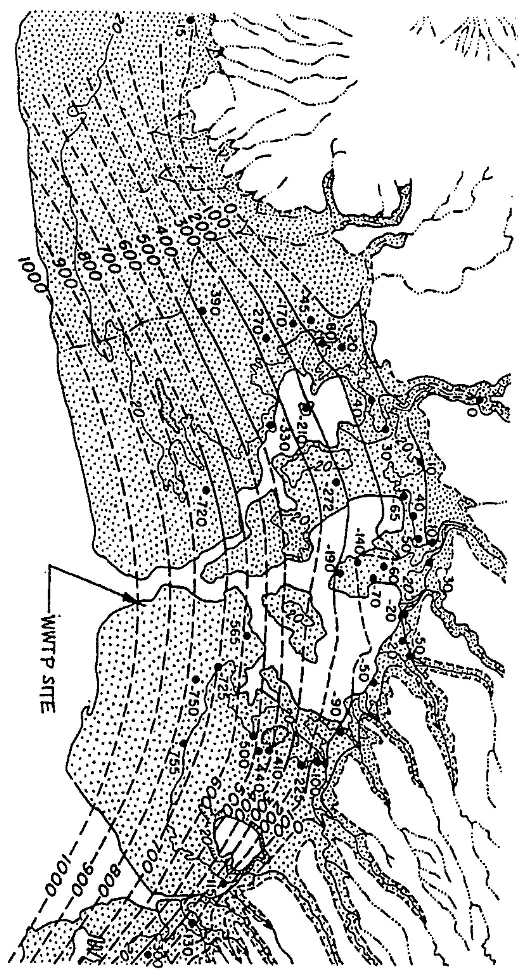
Resig, J.M. 1969. Paleontological Investigations of Deep Borings on the Ewa Plain, Oahu, Hawaii. HIG-69-2, Hawaii Institute of Geophysics, University of Hawaii.

Stearns, H.T. and K.N. Vaksvik. 1935. Geology and Ground-Water Resources of the Island of Oahu, Hawaii. Bulletin 1, Division of Hydrography, Territory of Hawaii.

__________. 1938. Records of the Drilled Wells on the Island of Oahu, Hawaii. Bulletin 4, Division of Hydrography, Territory of Hawaii.

Stearns, H.T. 1939. Geologic Map and Guide of the Island of Oahu, Hawaii. Bulletin 2, Division of Hydrography, Territory of Hawaii.

Visher, F.N. and J.F. Mink. 1964. Ground-Water Resources in Southern Oahu, Hawaii. USGS Water Supply Paper 1778, U.S. Government Printing Office, Washington, D.C.



EXPLANATION

—1000—

Structure contour
Drawn on the base of the caprock. Dashed where approximate
Contour interval 100 feet; datum is mean sea level

-750•
Well and depth of base of caprock, in feet below sea level

FIGURE 6.—Map of the Pearl Harbor area. Contour lines show the depth of the base of the caprock below sea level as indicated by well logs.

Source: Visher & Mink (1964:16)

Figure 2
Depth of the Volcanics in the Pearl Harbor Area

Appendix IV

Preliminary Geotechnical Evaluation in Support of Draft EIS for Ocean Outfall Extension, Fort Kamehameha, Pearl Harbor, Oahu, Hawaii*

PRELIMINARY GEOTECHNICAL EVALUATION

OCEAN OUTFALL EXTENSION WASTEWATER TREATMENT PLANT AT FORT KAMEHAMEHA

DEPARTMENT OF THE NAVY
PACIFIC DIVISION
NAVAL FACILITIES
ENGINEERING COMMAND

PEARL HARBOR, OAHU, HAWAII

Submitted by:

SSFM Engineers, Inc.
501 Sumner Street, Suite 502
Honolulu, Hawaii 96817

May 5, 1997

PRELIMINARY GEOTECHNICAL EVALUATION

OCEAN OUTFALL EXTENSION WASTEWATER TREATMENT PLANT AT FORT KAMEHAMEHA

PEARL HARBOR, OAHU, HAWAII

Prepared for:

SSFM Engineers, Inc.
501 Sumner Street, Suite 502
Honolulu, Hawaii 96817

May 2, 1997

Woodward-Clyde

Woodward-Clyde Federal Services
1144 Tenth Avenue, Suite 200
Honolulu, Hawaii 96816-2497

HI74

Section

1.1 Project Understanding

The Department of the Navy is proposing the construction of a new ocean outfall for Wastewater Treatment Plant (WWTP) at Fort Kamehameha. The new outfall will extend from the existing WWTP at Fort Kamehameha to a location 3,800 meters (12,500 linear feet) offshore, near the entrance to Pearl Harbor (Figure 1). This report was prepared in support of the Draft Environmental Impact Statement currently being prepared by SSFM Engineers, Inc. for this project.

Construction of this outfall would involve the installation of 1,050-millimeter (42-inch) internal diameter outfall pipe to a diffuser located offshore, at depths of 46 meters (Option 1) or 21 meters (Option 2) below sea level (Figure 2). The Draft Environmental Impact Statement (DEIS) proposes the use of high density polyethylene pipe (HDPE) for the outfall extension. The proposed outfall will operate primarily as a gravity line. Depending on the effluent discharge flow volume, the effluent pumps at the WWTP may be used to increase effluent discharge. Both open cut construction methods, trenchless construction methods, and a combination of open cut and trenchless methods are being considered for installation of this outfall.

A number of alternate pipeline alignments was considered inorder to reduce potential adverse environmental impacts to the coastal environment and disruption to ship traffic. The preferred outfall alignment selected by the project team is shown on Figure 2.

1.2 Purpose and Scope of Services

The purpose of this preliminary geotechnical evaluation is to explore the subsurface conditions at three locations along the proposed outfall alignment, and to make a preliminary evaluation of the feasibility of constructing the proposed outfall using either open cut or trenchless construction methods.

Specifically, the scope of our services included the following:

- field explorations consisting of three test borings;
- laboratory testing of selected samples;
- preliminary geotechnical evaluation of open cut and trenchless construction methods and;
- preparation of this report.

Woodward-Clyde Federal Services (WCFS) also provided geotechnical consultation services relating to aspects of construction concepts and revisions to the Parametric Cost Estimate (PCE). Our services were performed in general accordance with WCFS' January 21, 1997 revised proposal, and SSFM Engineers, Inc.'s February 3, 1997 and March 4, 1997 Notice to Consultant.

A specific construction method for the proposed outfall extension has not been determined. At the DEIS stage, the project study team's approach is to consider both open trench excavation and trenchless pipe installation methods. The study team has not determined whether the proposed pipeline may be installed solely using open trenching or trenchless technologies.

Depending on operational requirements, environmental impacts, subsurface conditions revealed during design investigations, and design requirements, an appropriate combination of both methods (open trench and trenchless construction) in the design and construction phases of the proposed pipeline may be considered.

The geotechnical exploration for this preliminary evaluation consisted of one onshore boring and three offshore borings adjacent to the proposed outfall alignment. Borings were completed on March 17 through 19, 1997. The location of Borings F2, F3, and F3A was estimated in the field using Global Positioning System equipment. Boring locations are shown on Figure 2. The borings were drilled to the following depths:

Boring Number	Measured Water Depth	Total Depth Drilled
F1	Land Boring	21 m (70 feet)
F2	12 m (40 feet)	37 m (120.5 feet)
F3	7.3 m (24 feet)	35 m (115.5 feet)
F3A	7.3 m (24 feet)	7 m (28.5 feet)

Hawaii Test Borings, Inc. was subcontracted to perform the land and offshore borings. Boring F3A was abandoned and relocated to location F3 due to adverse wave conditions at time of drilling. A Mobile Drill B-53 drill rig was mounted on a 55 m (180 ft) long, 15 m (50 ft) wide barge for the offshore borings. Woodward-Clyde personnel coordinated the field work and logged the borings. Samples were obtained from the above borings at approximately 1.5 m to 3 m (5 to 10 ft) intervals. A description of field exploration methods and the exploratory boring logs is presented in Appendix A.

The samples obtained were returned to our laboratory in Honolulu for further examination and testing. Selected samples were sent to our soil testing laboratory in Pleasant Hill, California for further examination and testing. Soils testing consisted of moisture content, dry density, sieve/gradation analyses, hydrometer/gradation analyses, Atterberg Limits (Plasticity Index), and Unconfined Compression Strength tests. Results of the laboratory tests are presented in Appendix A.

Based on the results of our preliminary field exploration and laboratory testing program, and a review of oceanographic information reported by Sea Engineering, Inc. for this project, we completed a preliminary evaluation of the general geology of the study area. Available subsurface information indicates that it appears that either open cut trenching or trenchless construction methods could be used to install portions of the proposed ocean outfall; however, additional data must be collected to confirm this preliminary assessment and more detailed construction planning evaluations are needed to develop feasible construction approaches.

3.1 Regional Geology

Pearl Harbor, which consists of three lochs, was formed by a series of drowned river valleys. Past geotechnical explorations performed in the WWTP at Fort Kamehameha area, the Geological and Topographic Map of Oahu (U.S.G.S., 1938), and underwater reconnaissance performed by Sea Engineering, Inc. for this project indicate that the subsurface conditions along the proposed outfall probably consist primarily of interbedded marine and estuarine deposits.

Fine-grained estuarine sediments, consisting primarily of silts and clays, were deposited in the study area due to sea level fluctuations in the last million years. These fine-grained sediments may have soft to very stiff consistencies. However, firmer and stronger sediments may be present throughout the estuarine sediments. Fluctuation of sea levels have resulted in formation of coral reefs and variable consolidated reef detritus at various elevations.

Marine deposits in the Pearl Harbor Entrance Channel area are expected to consist mainly of fine to coarse grained sediments. Coralline deposits consisting mostly of hard cemented coral layers or ledges and uncemented to slightly cemented coralline detritus may also be present. Coralline deposits may consist of coralline sands, gravels, and coralline cobbles 7 to 12 cm (3 to 12 inches) to boulders greater than 30 cm (12 inches).

An approximately 1.5m to 3m (5 to 10 feet) thick layer of volcanic tuff was encountered at depths of about 15m to 18m (50 to 60 feet below MSL) in many borings drilled at the WWTP site. It is not known whether the areal extent of this volcanic tuff layer extends to the Pearl Harbor Entrance Channel. The available hydrographic survey data by Sea Engineering, Inc. indicate that the seafloor depth is approximately 15m (50 feet) below mean sea level within the Pearl Harbor Entrance Channel.

3.2 Preliminary Assessment of Subsurface Conditions

Soil conditions are described with respect to the Unified Soil Classification System (USCS) summarized on Plate A-2. Boring F1, completed onshore between the WWTP at Fort Kamehameha and the shoreline (Figures 1 & 2), encountered loose to very dense silty sands (SM), very loose to loose gravelly reef detritus (GM, GW-GM), very stiff estuarine clays (CL) and silts (MH), and friable to hard volcanic tuff. The volcanic tuff was bedded, moderately weathered and contained layers of silty sand (SM) and sandy silt (ML). The volcanic tuff was encountered at a depth of about 19m, (elevation 18m below MSL). Water was encountered at 75 cm below ground surface (elevation 15m below MSL).

Marine sediments encountered in Boring F2, completed about 1,340 m (4,400 feet) offshore from the WWTP at Fort Kamehameha, consisted primarily of very loose to medium dense silty sand (SM), a 2-m (7-foot) thick layer of very soft silt (ML), and a 2.5-m (8-foot) thick layer of gravel to cobble sized reef detritus (GP-GM).

Boring F3, completed near the edge of the present day fringing reef platform, encountered primarily very loose to very dense gravelly reef detritus (poorly graded gravel, GP, and silty gravel, GM), with some interbedded layers of recent marine sediments consisting primarily of fine sand (SP) and very soft to soft silt (MH). The reef deposits included cobble sized coral

chunks, and locally cemented layers or zones. A hard zone, probably composed of cemented coral or coralline cobbles or boulders, was encountered in Boring F3 approximately between elevation 19.5m and 20m (65ft to 67ft) below MSL. A hard zone was also encountered in Boring F3A below approximate elevation 8m (27.5ft) below MSL. The extent of this hard zone could not be determined since weather conditions made further exploration at Boring F3A impossible.

The amount of gravel present along the alignment may impact the feasibility of using the Horizontal Directional Drilling (HDD) technique. This issue is discussed further in Section 4.2.1. A summary of grain size distribution test results is presented in the following table.

Boring # - Sample #	Depth m	Gravel Content (%)	Sand Content (%)	Fines Content (%)
F1-1-1	2.7 to 3.2	59	36	5
F1-4-2	5.6 to 6.1	25	65	10
F1-5-1	7.2 to 7.6	10	49	41
F1-6-2	8.7 to 9.2	32	41	27
F2-3-1	15 to 15.5	0	24	76
F2-5-1	16.5 to 17	47	41	12
F3-6-1	22 to 22.4	62	34	4
F3-7-1	25 to 25.5	1	94	5
F3-8-1	28 to 28.5	43	40	17
F3-9-1	31.1 to 31.6	48	42	10
F3-10-1	34.1 to 34.6	51	45	4

3.3 Marine Seismic Refraction Survey by Others

Loose sand deposits appear to underlie the pipeline and diffuser from approximately Station 33+00m (108+00 feet) to the end of the diffuser at Station 39+30m (129+00 feet) based on an underwater reconnaissance and marine seismic refraction survey performed by Sea Engineering, Inc. The seismic refraction survey results are presented in Appendix B. A cross section showing preliminary geologic data along the proposed alignment is presented on Figure 3. The origin of this sand body is not known at this time. Sand layers are estimated by Sea Engineering, Inc. to be approximately 3m to 9m (10 to 30 feet) thick.

Two basic methods for construction of the ocean outfall are being considered for this project: open cut trenching and trenchless construction methods. A brief description of the methods and preliminary discussions of the advantages and disadvantages of these methods is presented below. A preliminary evaluation of the open cut trenching construction method was conducted by Belt Collins Hawaii and Sea Engineering, Inc. for the DEIS. For completeness, this report includes sections of the DEIS describing open cut trenching methods that are to be addressed in this preliminary evaluation.

Trenchless construction methods can be used to reduce the potential adverse environmental impacts of construction; however, it appears that the requirements of this project are unprecedented due to the length of the outfall, 3,800m (12,500ft), which exceeds the current limits of typical trenchless installations. For example, the longest single run completed by horizontal directional drilling methods to date is about 1,800m (5,850ft) and most microtunneling drives are less than about 460m (1,500ft). A recent project in Germany involved the installation of a 3m internal diameter concrete pipe about 2.6km offshore in a single drive for a gas pipeline. This is an unusually long drive length (World Tunneling, 1994).

It is likely that complicated construction staging over water would be required. Depending on actual subsurface conditions, environmental impacts, and design requirements, a combination of the two methods (open cut trenching and trenchless construction methods) may be appropriate in terms of minimizing environmental impacts, construction costs, and construction risks. This approach would require the project planning, geotechnical investigation, and design efforts to adequately evaluate both open trenching and trenchless construction methods. At this preliminary stage, the potential use of both open cut trenching and trenchless construction methods along the entire outfall alignment (except in the diffuser area) is being considered.

Very loose to medium dense sand deposits may become unstable under static, dynamic, and hydrodynamic loading induced by new overburden loads, impact, seismic and wave induced conditions. Regardless of the construction method selected, an evaluation of the liquefaction potential should be made since large portions along the proposed outfall alignment appear to consist of loose to medium dense sand deposits.

4.1 Open Cut Trenching Methods

Construction in the Reef Flat

Open trenching along the shallow portion of the reef flat can be achieved by means of large rubber-tired or tracked excavation and hauling equipment. A construction corridor approximately 15m (50ft) wide should be established within which all vehicle operation and excavation should be confined. The pipe will be placed in a trench approximately 2.6m (9ft) deep and protected with tremie concrete or articulated concrete mats. The top 0.3m (1 ft) will be backfilled with native material or coral sand. With the use of matting, large equipment will be able to work on the reef flat to a water depth of approximately 1m (3ft).

Construction in the Pearl Harbor Entrance Channel

Where the outfall alignment follows the edge of the Pearl Harbor Entrance Channel, the pipe is planned to be placed in a trench approximately 3.8m (12.5ft) deep, so that it will be beneath anticipated future maintenance dredging limits, and protected by tremie concrete or articulated concrete mats. Construction in this area would be performed from barges. Loose sediments may be dredged and rock material may be excavated using spudding or blasting. The subsurface conditions along this portion of the proposed pipeline alignment are not known at this time.

SECTIONFOUR Preliminary Construction Methods Evaluation

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Construction Through the Rock Area

From the seaward end of the Pearl Harbor Entrance Channel to the 20m (65ft) depth, a distance of approximately 700m, Sea Engineering, Inc. observed that the sea floor consists of limestone and coral rubble. From a construction standpoint, blasting may be the economical method for excavation of hard, cemented coralline limestone. If blasting is not allowed, spudding may be necessary. The pipe is planned to be placed in a trench approximately 2.6m (9ft) deep and protected with tremie concrete or articulated concrete mats. Construction in this area would also be performed from barges.

Construction of the Diffuser in the Sand Area

Through the relatively steep sand slope, from the 20m (65ft) to 40m (130ft) depths, construction of the outfall will require the installation of driven piles, adequately embedded to a competent bearing layer, to support the pipeline. The pipe can be structurally tied to underlying pile caps and tie-beams placed above the surface of the sea floor. This approach will facilitate installation of the pipe, as well as any future repairs that may be required, in the event that the pipe is damaged.

4.1.1 Advantages of Open Cut Trenching

Compared to trenchless construction methods, open cut trenching is generally less sensitive to subsurface uncertainties and potential obstructions. Potential layers of hard, cemented coral materials along the deeper portions of the proposed pipeline corridor can be excavated either by

blasting (by placed shape charges), if allowed by the U.S. Navy and applicable permitting agencies, or by spudding.

Most of the excavation and spoil removal work can be performed by conventional mechanical excavators and barge based dredging and spudding equipment.

4.1.2 Disadvantages of Open Cut Trenching

Open trenching is expected to have the following risks and potential environmental impact:

- If hard cemented coral or volcanic tuff layers are encountered in the deeper portions of the alignment, blasting or spudding will be required to excavate the hard rock ledges. If blasting is not permitted by the U.S. Navy or the permitting agencies, spudding will be required. The need to spud will slow down the excavation process significantly, and will increase excavation costs.
- Blasting, such as by placed shape charges, at or near the toe of steep slopes may trigger submarine rock falls or slides, due to the presence of steep to vertical channel walls along the Pearl Harbor Entrance Channel.
- Approximately 15m by 1,100m, or 16,500 square meters (177,500 square feet) of shallow reef areas will be disturbed by the construction work.
- Approximately half of the Pearl Harbor Entrance Channel will need to be temporarily closed to shipping traffic during construction along the channel. An alternative anchoring scheme to prevent closing of the entrance channel is presented in the DEIS.

- Environmental sampling and testing, including bioassays, may be needed to evaluate if the dredged bottom sediments would be toxic to aquatic organisms.

4.2 Trenchless Construction Methods

Trenchless construction methods will probably be desirable for the construction of at least a portion of the proposed outfall in order to reduce potential adverse environmental impacts due to construction and disturbance to the marine environment. Two trenchless construction methods have been considered in this preliminary evaluation: horizontal directional drilling (HDD) and microtunneling.

4.2.1 Horizontal Directional Drilling

Horizontal directional drilling (HDD) is a drilling technique which uses a guided drilling bit to drill a pilot hole which is subsequently enlarged by reaming with various reaming tools to obtain a hole of the desired size. Drilling mud is used to flush the cuttings from the hole and to stabilize the hole to prevent caving. When the hole has reached the required size, the carried pipe (or a casing) is pulled back into the hole in a single operation (Figure 5). Typically, the profile has at least two vertical curves (due to entry and exit points requirements) . The drill profile can also accommodate horizontal curves but straight alignments are preferred. The line and grade control of this method is usually not as accurate as microtunneling, but may be adequate for this project.

The actual path of the pilot hole is monitored during drilling by taking periodic readings of the inclination and azimuth of the leading edge of the installed drill string. Readings are taken with an instrument, commonly referred to as a probe, inserted in a drill collar as close as possible to the drill bit. Transmission of downhole probe survey readings to the surface is generally accomplished through a wire running inside the drill string. These readings, in conjunction with

measurements of the distance drilled since the last survey, are used to calculate the horizontal and vertical coordinates and elevation of the drill bit along the pilot hole relative to the initial entry point on the surface.

In general, the line and grade accuracy of pipeline installation by directional drilling is about +/- 0.6m for a 300m (1,000ft) length of pipe. Horizontal deviation from the alignment may vary depending on the subsurface conditions. The contractor will need to track the drilling head during directional drilling. Tracking instruments embedded beneath the sea floor bottom may be needed to monitor the location of the drill head.

Conceptual HDD Approach for Constructing Outfall

At this preliminary stage, the outfall could be installed in at least three main segments described as follows:

- Station 0+00 to 11+00 m (4,000 feet) - Drill from the proposed construction staging area outside the WWTP, 3m to 5m beneath the shallow reef, to an intermediate drilling platform at about Station 11+00 m. The drilling platform may be pile supported. A protective steel casing tied to the exit location and extending to the drilling platform may be required to contain the drilling slurry and facilitate back reaming the pilot hole and subsequent pipe pulling. A protective steel casing would be placed between the exit pit and drilling platform to allow installation of the back-reamer. The first 1,100 m of pipe would be pulled from the WWTP to the platform.

- Stations 11+00m to 24+40m (or the "Sand Area") - Directional drilling may be performed on an offshore drilling platform or barge. The drilling platform or barge will need to be stabilized and supported by steel piles or other anchors to provide a stable platform for

directional drilling and pulling of the HDPE pipe string. The drill platform can be positioned at Station 24+40m, and drill towards and pull pipes from Station 11+00m, and then turn 180 degrees to drill and pull pipes from Station 36+00m.

For HDD methods, an important design consideration for the pipe is the tensile stresses that are imposed when they are pulled into place through the drill hole. Another important design consideration is the corrosion resistance of the pipe. The most common pipe installed using HDD methods are welded steel and HDPE pipes. Either of these pipes should be adequate for the outfall, although a welded steel pipe would need to be lined and coated to protect against corrosion. A steel pipe may also require cathodic protection.

An HDPE pipe cannot sustain as long a pullback as a welded steel pipe. If HDPE pipe is selected, it is likely that the outfall would have to be constructed in more than three segments; possibly as many as six segments - this would require more over-water work. Available information regarding HDD installations that appear to define the state of the art in length and diameter as of 1997 are summarized as follows:

Location	Length, m (ft)	Diameter, cm (in)	Soil Origin	Pipe Type	Date
Yorktown, VA	1,783 (5,850)	25 (10)	Alluvial	Steel	1994
Norfolk, VA	658 (2,160)	122 (48)	Alluvial	Steel	1994
Sacramento, CA	1,219 (4,000)	107 (42)	Alluvial	Steel	1995
Everett, WA	457 (1,500)	137 (54)	N/A*	HDPE	1995
Sacramento, CA	1,158 (3,800)	107 (42)	Alluvial	Steel	1995
Sacramento, CA	854 (2,800)	107 (42)	Alluvial	Steel	1995

* Pipe pulled within pre-existing carrier pipe

Horizontal directional drilling methods are expected to be fairly well suited to the soft soils and sandy deposits, such as the estuarine and beach deposits encountered in Borings F1, F2, and F3. Directional drilling has also been used in silty sand and gravelly sand deposits. However, hard volcanic tuff or cemented coral reefs and coralline deposits with gravel contents greater than 50 percent may be problematic leading to difficulty in drilling the pilot hole and caving in of the hole. In addition, coralline deposits, consisting mostly of sandy gravel and gravel may come into the drill hole and obstruct or divert the pipe string during pipe pullback. Careful evaluation and selection of the pipe alignment and profile supported by adequate geotechnical information will be important steps in the design phase of this project, if HDD methods are to be used.

Horizontal directional drilling would require a long lay down area to lay a pipe string for pull back. This can be achieved by floating and adjusting the buoyancy of the pipe string and lay down in the water. Installation of HPDE pipes by the open trench method would also require similar procedures.

Some important design and construction considerations for HDD methods include:

- Adequate staging area for drilling equipment an area of approximately 45 by 45 meters (150 feet by 150 feet).
- Feasibility of setting up drilling operations on a platform in the ocean.
- Adequate ground cover to prevent blow out and escape of drilling fluids..
- Extensive layout area required for final pipe string pull.
- Need for drilling fluid containment at the entry and exit locations.
- Adequate geotechnical investigation prior to the design phase.
- Detailed evaluation of soil types, grain size data, and properties to confirm that HDD methods are feasible.

- For planning purposes, and during the EIS review and approval process, we recommend that the proposed pipeline alignment be widened to a proposed pipeline corridor of at least 50 meters wide.

4.2.2 Microtunneling

Microtunneling is an underground method of constructing pipelines using a remote controlled, laser guided, steerable tunnel boring machine. The pipe is installed using pipe jacking methods from a jacking pit to a receiving pit. The alignment and profile of the pipeline must be straight, with no curves, in order to avoid eccentric stresses which could damage the jacking pipe. The line and grade accuracy of this method is good when properly executed. Maximum drive lengths using microtunneling methods are typically about 300m to 600m.

Based on available information, pipeline installation costs using the microtunneling method may be substantially reduced if the pipeline corridor is located above and adjacent to the Pearl Harbor Entrance Channel. This alignment would reduce access shaft depths.

If microtunneling is used to install most of the proposed pipeline, a total of 9 to 12 access shafts may be required. Shaft depths may need to be about 15m (50ft) deep near the WWTP at Fort Kamehameha to 45m (150ft) deep near the diffuser section. A possible combination of microtunneling and horizontal directional drilling may reduce the numbers and depths of access shafts and allow for more stringent line and grade control (Figure 4). Offshore drives (microtunnel segments) should progress upgrade to provide drainage (slurry removal of cuttings) back to the jacking pit.

Conceptual Microtunneling Approach for Constructing Outfall

At this preliminary stage, the outfall could be installed as described below. A combination of microtunneling and HDD methods may also be possible.

- Stations 0+00m to 11+00m (40+00ft) - This section may be constructed using HDD or microtunneling. If microtunneling methods are used, at least three or four 8 to 9m (25 to 30ft) diameter shafts will be needed in this area for jacking and receiving pits. Equipment access to the shallow reef flat may be similar to the open trench method as discussed in Section 4.1.1. Shafts may be constructed by installing sheet piles and appropriate ground improvements at the shaft location. A small barge or platform will be required to stage equipment and slurry/solid control systems next to the access shaft.
- Stations 11+00m (40+00ft) to 24+40m (80+00ft) - Microtunneling methods for this section would involve about 2 or 3 additional access shafts for jacking and receiving pits. Ancillary equipment, supplies, and slurry/solid control systems may be staged on barges moored next to the shafts or on platforms.
- Stations 24+40m (80+00ft) to 35+00m (116+00ft) - For this section, at least one access shaft will need to be constructed to a depth of approximately 45m (150ft) in addition to 1 or 2 shallower shafts. The 45m shaft would be located approximately 460m (1,500ft) from the proposed diffuser location. Special shaft sinking methods and procedures will be required at a substantial cost. A specially designed microtunneling machine will be needed to safely install the pipe under 45m (150ft) of hydrostatic head. Alternatively, HDD or open trenching may be used to install the pipeline within this section (Figure 4).

For microtunneling, the primary consideration for pipe materials is its ability to withstand the significant compressive axial loads during installation by pipe jacking. Pipe sizes are generally

in the range between 30cm (12in) and 150cm (60in). The following types of pipe are generally used for microtunneling applications:

- Concrete
- Clay
- Fiberglass
- Polymer Concrete
- Welded steel pipe
- Steel Casing (with HDPE, PVC, ductile iron, or coated steel carrier pipe installed inside the casing)

If steel casing is used, carrier pipes other than those listed above can be installed inside the casing and grouted into place. For an offshore installation, concrete, fiberglass, welded steel, or a steel casing would likely be used.

Microtunneling is not suitable for the direct installation of high density polyethylene (HPDE) pipe because it cannot withstand the jacking forces without damage. To install HDPE pipe using microtunneling methods, a steel casing will need to be installed first, then the HDPE pipe can be installed inside the steel pipe. The annulus between the steel and HDPE pipe is filled with grout to complete the installation.

Microtunneling performs well in soft soils, such as the estuarine soils encountered in Borings F1 and F2. Microtunnel boring machines (MTBM) also generally perform well in stiff soils, with some exceptions. Rock types such as the volcanic tuffs or cemented coral reef rock at this site will require a special rock cutterhead on the MTBM.

The potential for obstructions during microtunneling needs to be evaluated carefully. Obstructions can include cobbles and boulders, highly welded tuffs, and strongly cemented coral

reef rock. Dramatic changes in subsurface conditions along the alignment, such as soft soils over welded tuff or cemented coral reef deposits, can create steering difficulties for the machine. Selection of the alignment and profile along with specific contingency planning for construction is critical.

4.2.3 Advantages of Trenchless Construction Methods

The use of trenchless construction methods will reduce disturbance to the shallow reef and other parts of the ocean environment. If trenchless methods are used, the outfall alignment can be offset 50m east, away from the entrance channel, to minimize impacts to shipping traffic. The need for blasting would also be avoided except at some access shaft locations if microtunneling methods are used, and there is a need to excavate hard rock during shaft construction.

4.2.4 Disadvantages of Trenchless Construction Methods

Trenchless construction methods for this project require more extensive geotechnical investigations to define subsurface conditions and more detailed research because of the unprecedented nature of the work, and a more thorough evaluation of construction equipment requirements. Unforeseen problems encountered during construction can be very costly. Successful directional drilling or microtunneling will depend on an accurate understanding of the subsurface conditions. Potential subsurface uncertainties can be reduced by extensive geotechnical investigations during design, marine seismic refraction surveys, and underwater reconnaissance of the exposed channel walls and sea floor. Risks relating to potential obstructions can be reduced by selecting a favorable alignment and profile that allows reasonable access from the surface to remove any obstructions encountered during construction. Because of the unprecedented nature of this installation and the offshore location of the pipeline, trenchless

construction methods is likely to cost more than a land-based trenchless construction project, although detailed cost estimates have not been prepared.

SECTIONFIVE Limitations

This report has been prepared for the exclusive use of the U.S. Navy and SSFM Engineers, Inc., in accordance with generally accepted geotechnical engineering practices. The preliminary evaluations, conclusions, and recommendations presented in this report should be reviewed and revised during the design phase when additional data is available. The sole intent of our preliminary discussions of construction concepts are to assist with the preparation of the Draft Environmental Impact Statement in discussing potential construction options and possible constraints relating to the proposed outfall extension. No other warranty, expressed or implied, is made as to the professional advice included in this report.

Additional geotechnical data, preliminary design evaluations, and more detailed construction methods assessments will be required to establish the feasibility of specific construction methods and to determine a recommended horizontal and vertical alignment for the outfall.

The borings completed for this report are widely spaced and significant variations in subsurface conditions should be expected between these borings. The actual nature of the subsurface conditions may not become evident until the design phase of this project, or during construction. This preliminary report has been developed for the use of the U.S. Navy, SSFM Engineers, Inc. and their consultants; it does not contain sufficient information for detailed construction planning, final design, or bidding.

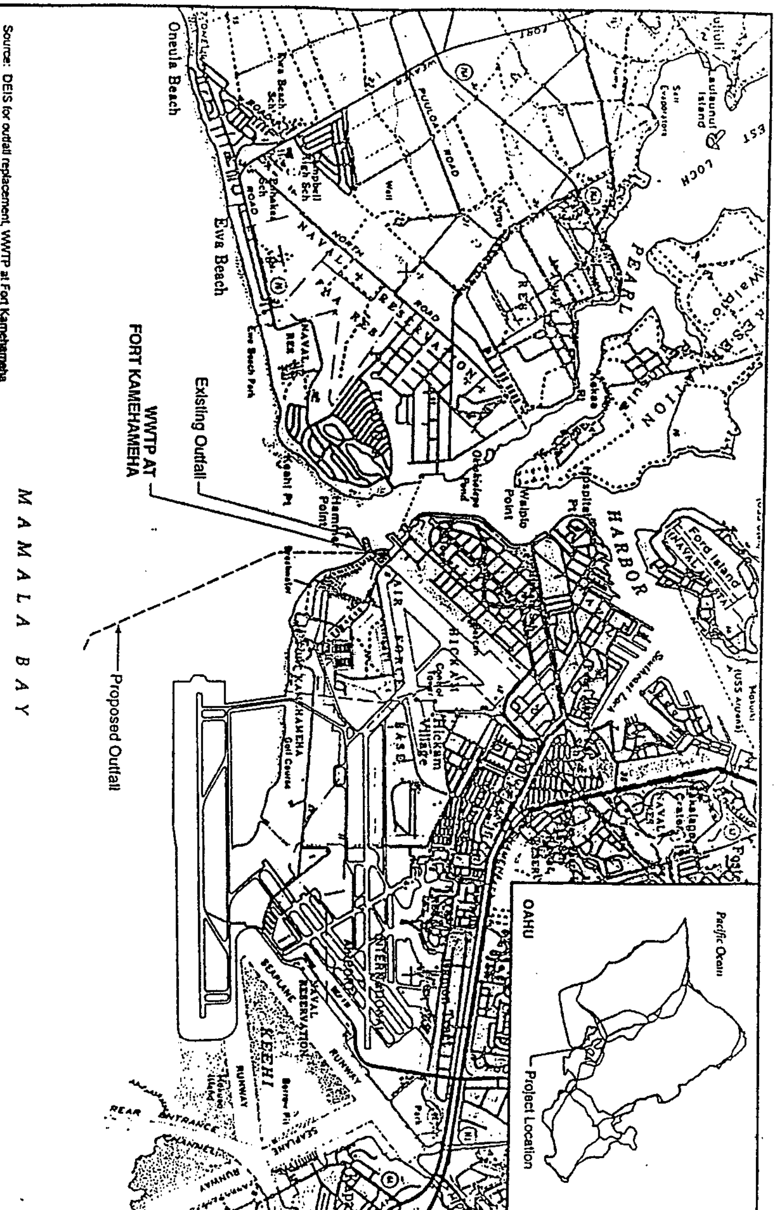
The scope of our services for this project was limited to conventional geotechnical engineering services and did not include any environmental or hazardous waste assessment or evaluations. Silence in this letter report regarding any environmental or hazardous waste aspects of the site does not indicate the absence of potential environmental problems.

Martin Cherrington, May 1993. *A 4,000-ft River Crossing With a 60-in Diameter Cutter Head.* Institute of Shaft Drilling Technology, International Conference on Shaft Drilling Technology.

Sea Engineering, Inc. *Oceanographic Study for MCON Project P-497, Extend Ocean Outfall, Wastewater Treatment Plant at Fort Kamehameha, Section 4.0 Bathymetry and Bottom Conditions. Provided by SSFM Engineers, Inc. on December 6, 1996.*

SSFM Engineers, Inc., March 1997. *Draft Environmental Impact Statement, Outfall Replacement for Wastewater Treatment Plant at Fort Kamehameha, Navy Public Works Center, Pearl Harbor, Hawaii. (Working Copy).*

World Tunneling, 1994. *"Europipe Sets the Record."* Volume 7, Number 7, September, P.283-285.



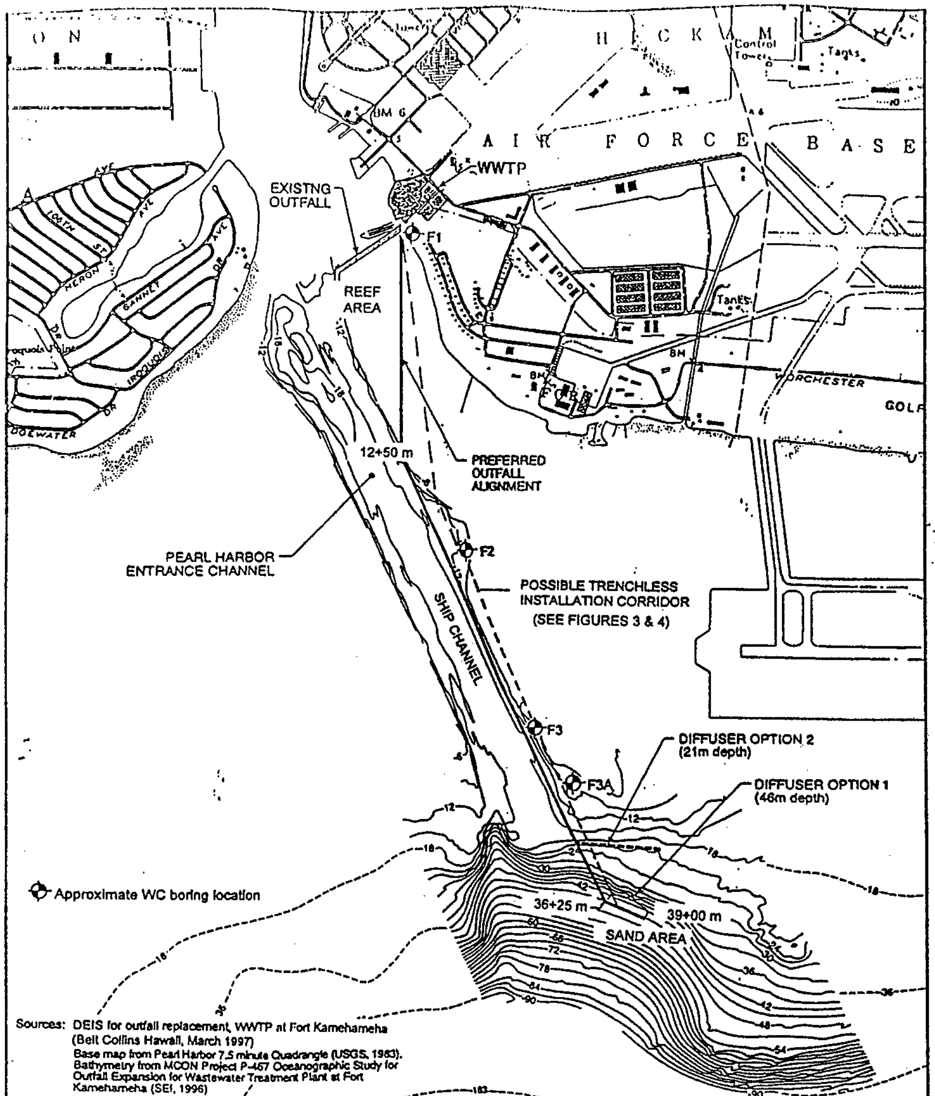
Source: DEIS for outfall replacement, WWTP at Fort Kamehameha (Belt Collins Hawaii, March 1997)

Source: Topographic map of Oahu (USGS, 1954)

NORTH

0 400 800 2000m
SCALE IN METERS 1:60,000

Figure 1
PROJECT LOCATION MAP



Sources: DEIS for outfall replacement, WWTP at Fort Kamehameha (Belt Collins Hawaii, March 1997)
Base map from Pearl Harbor 7.5 minute Quadrangle (USGS, 1983).
Bathymetry from MCON Project P-467 Oceanographic Study for Outfall Expansion for Wastewater Treatment Plant at Fort Kamehameha (SEI, 1996)

NORTH

0 200 500m

SCALE IN METERS 1:24,000

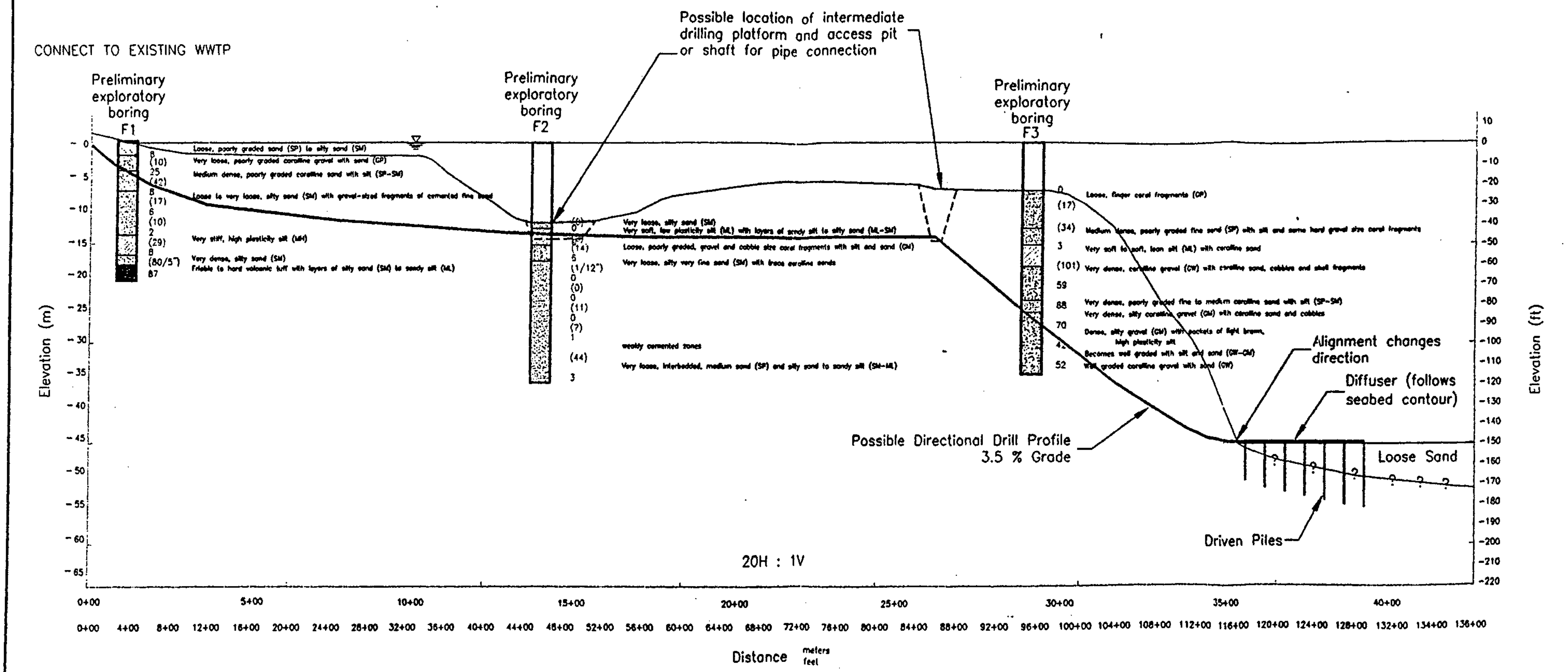
LEGEND

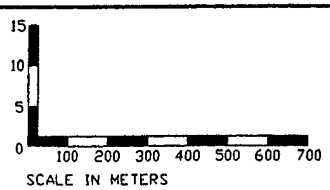
--6-- Bathymetry (in meters) from USGS topographic map

—6— Bathymetry (in meters) from SEI study

Figure 2

PROPOSED OUTFALL ALIGNMENT AND APPROXIMATE BORING LOCATIONS





LEGEND

- Very Soft to Soft Clayey/Silty Deposits
- Med. Stiff to Hard Clayey/Silty Deposits
- Gravelly Deposits
- Sandy Deposits
- Tuffaceous Deposits

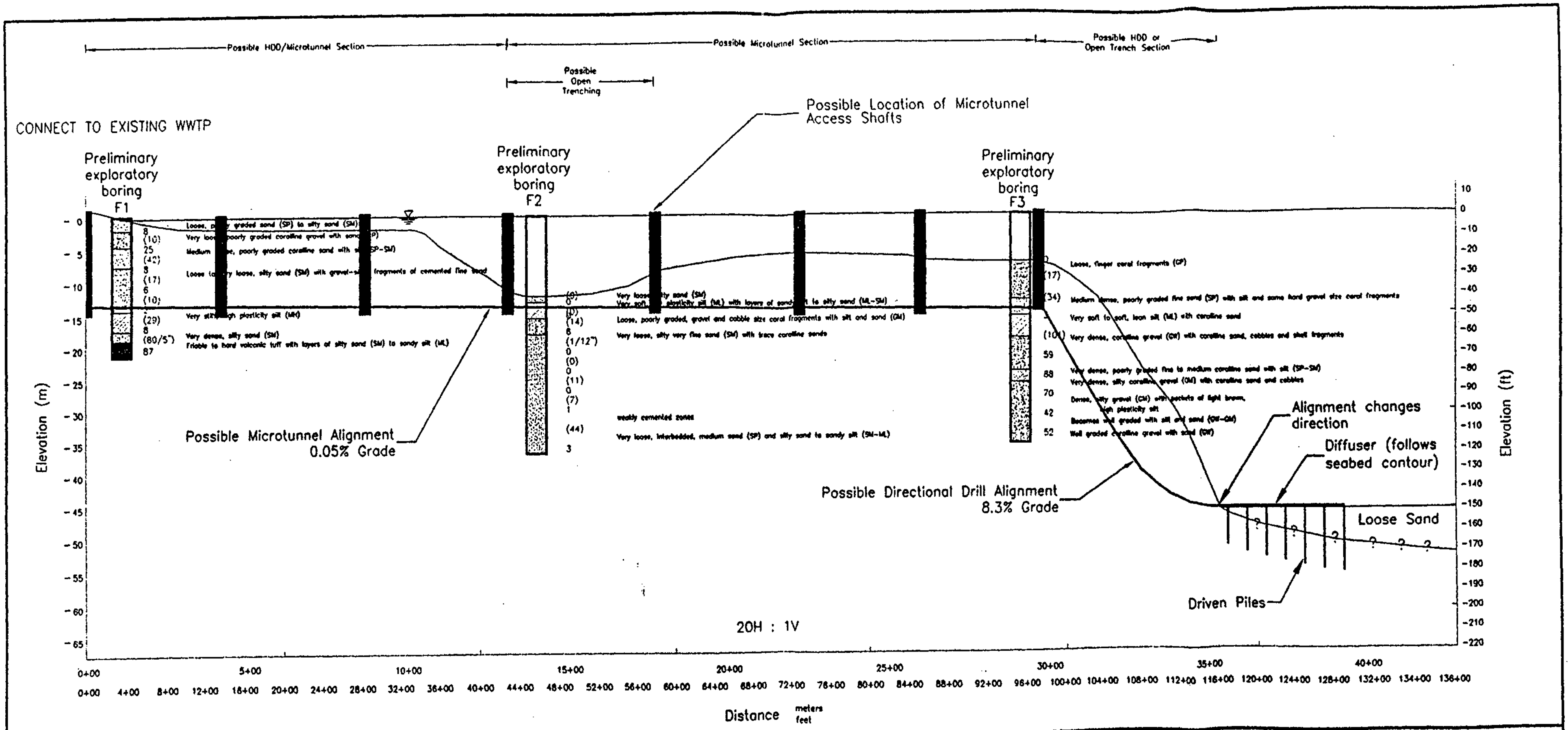
21 – Numbers Indicate Standard Penetration Test (SPT) Blowcounts

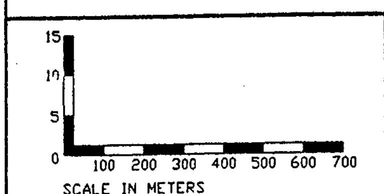
(21) – Numbers In Parentheses Indicate 3-inch Split Sampler Blowcounts

Figure 3

PRELIMINARY GEOLOGIC DATA AND EXAMPLE OF HORIZONTAL DIRECTIONAL DRILLING PROFILE

DEIS for Outfall Replacement,
WWTP at Fort Kamehameha, Pearl Harbor, Oahu, Hawaii
for SSFM Engineers, Inc.
Woodward-Clyde April 1997





LEGEND

- Very Soft to Soft Clayey/Silty Deposits
- Med. Stiff to Hard Clayey/Silty Deposits
- Gravelly Deposits
- Sandy Deposits
- Tuffaceous Deposits
- 21 – Numbers Indicate Standard Penetration Test (SPT) Blowcounts
- (21) – Numbers in Parentheses Indicate 3-inch Split Sampler Blowcounts

Figure 4

PRELIMINARY GEOLOGIC DATA AND EXAMPLE OF COMBINED HORIZONTAL DIRECTIONAL DRILLING AND MICROTUNNELING PROFILE

DEIS for Outfall Replacement, WWTP at Fort Kamehameha, Pearl Harbor, Oahu, Hawaii for SSFM Engineers, Inc.

Woodward-Clyde April 1997

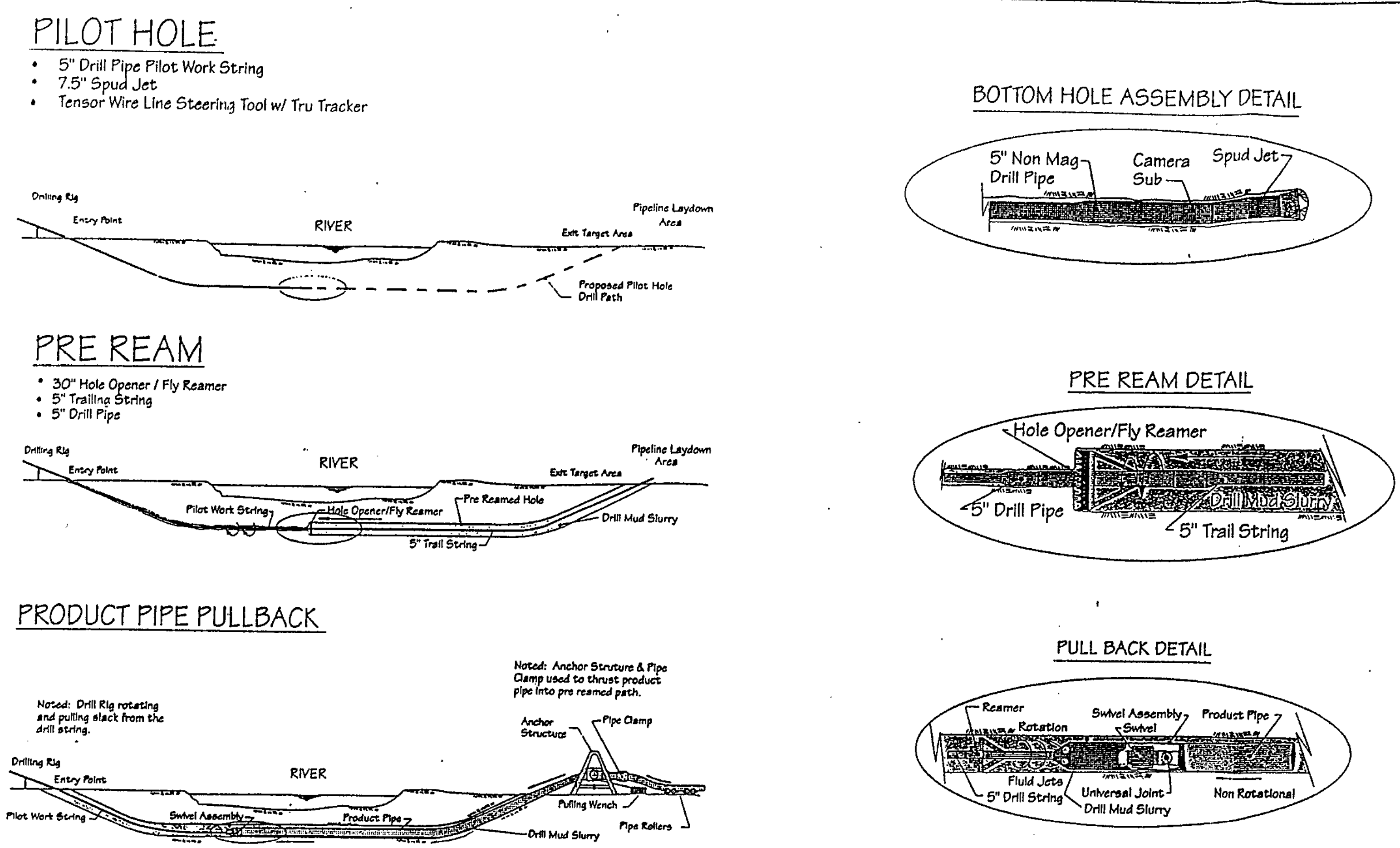


Figure 6
EXAMPLE OF HORIZONTAL DIRECTIONAL DRILLING PROFILE (RIVER CROSSING) AND PROCEDURES
DEIS for Outfall Replacement,
WWTP at Fort Kamehameha, Pearl Harbor, Oahu, Hawaii
for SSFM Engineers, Inc.
Woodward-Clyde April 1997
Source: Cherrington Corporation, 1995

The explorations for this study were conducted between March 17 and March 19, 1997. The exploration program consisted of drilling one (1) onshore boring to a depth of 21 m (70 feet) below ground surface and three (3) offshore test borings to depths ranging from 8.5m to 36.5m (28.5 to 120.5 feet) below sea level. One of the offshore borings, F3A, had to be relocated due to unsuitable ocean conditions at the time of drilling. A Mobile Drill B-53 truck mounted drill rig utilizing the rotary wash boring drilling method with 4 inch casing was used for all of the borings. The drill rig was mounted on a barge for the offshore borings. The approximate locations of the borings are shown on Figure 2.

Hawaii Test Borings, Inc. was subcontracted to drill the borings. The borings were performed under the technical observation of Woodward-Clyde engineering personnel who prepared a log of the materials encountered in each boring. These boring logs are included on Plates A1.1 through A1.4. A boring location plan is presented in Figure 2.

Relatively undisturbed and disturbed soil samples were obtained using two types of samplers; a standard penetration test (or split spoon) sampler and a 7.5-cm (3-inch) outside diameter (OD) California sampler with brass rings to contain the samples. Samples obtained with the SPT sampler have a diameter of 1.5 inches. Samples from the California sampler have a diameter of 2.5 inches. The samplers were driven with a 140-pound hammer falling 30 inches. The sampler was driven for a total distance of 18 inches, and the number of hammer blows (blowcount) for each 6 inches of penetration were recorded. Where the SPT sampler was used, this procedure follows ASTM Standard D3441 for determining the standard penetration resistance of soil. Blowcounts for the last 12 inches of penetration are noted on the Log of Borings and on Figure 3.

Samples recovered during the field exploration program were transported to our Honolulu office for further examination. Selected samples were tested at the Woodward-Clyde Geotechnical Laboratory in Pleasant Hill, California. Upon completion of drilling, the onshore boring was

backfilled to the ground surface using on-site soils and a plug, approximately 5-feet thick, of cement grout.

Soil samples recovered from the field were initially classified according to the American Society of Testing and Materials (ASTM) D4288 and Unified Soil Classification System, shown on Plate A-2. These classifications were later refined according to ASTM D2487 based on the results of laboratory tests performed on selected samples.

LABORATORY TESTING

To evaluate their engineering properties, selected soil samples obtained during the field exploration were tested to evaluate their laboratory moisture content, dry density, plasticity index (Atterberg Limits), representative grain sizes by sieve and hydrometer analyses, and unconfined compression strength tests on cohesive samples. The tests and results are described in the following paragraphs.

MOISTURE CONTENT AND DRY DENSITY

Relatively undisturbed selected soil samples were tested to measure their in-situ moisture contents and dry densities. The tests were performed in accordance with American Society for Testing and Materials (ASTM) D2216. Results of the moisture content and dry density tests are presented in the table below:

Boring #-Sample #	Depth, meters (feet)	Water Content, %	Dry Density, pcf (kN/m^3)
F1-1-1	1.5-2.0 (5-6.5)	34.0	Not tested, bag sample
F1-3-1	4.1-4.6 (13.5-15)	31.1	Not tested, bag sample
F1-4-2	5.6-6.1 (18.5-19)	38.1	78.3 (12.3)

F1-5-1	7.2-7.7 (3.5-25)	36.2	Not tested, bag sample
F1-6-2	8.7-9.2 (28.5-30)	43.5	75.3 (11.8)
F1-8-2	11.7-12.2 (38.5-40)	36.6	73.5 (11.6)
F1-9-1	13.3-13.8 (43.5-45)	32.8	Not tested, bag sample
F1-10-2	14.8-15.3 (48.5-50)	48.0	75.9 (11.9)
F1-12-1	17.8-18.1 (58.5-59.5)	21.6	Not tested, bag sample
F2-3-1	14.9-15.4 (49-50.5)	58.8	67.4 (10.6)
F2-3-2	14.9-15.4 (49-50.5)	56.4	72.1 (11.3)
F2-4-1	15.5-16 (51-52.5)	35.1	Not tested, bag sample
F2-6-1	18-18.5 (59-60.5)	37.8	Not tested, bag sample
F2-7-1	19.5-20 (64-65.5)	46.2	74.4 (11.7)
F2-9-1	22.6-23.1 (74-75.5)	47.7	71.7 (11.3)
F2-11-2	25.6-26.1 (84-85.5)	44.1	72.9 (11.5)
F2-13-1	28.6-29.1 (94-95.5)	38.4	83.2 (13.1)
F2-15-2	33.2-33.7 (109-110.5)	33.5	85.0 (13.4)
F3-2-1	9.8-10.3 (32-33.5)	24.5	Not tested, bag sample
F3-3-1	13.1-13.6 (43-44.5)	32.5	Not tested, bag sample
F3-7-1	25-25.5 (82-83.5)	27.5	Not tested, bag sample
F3-8-1	28-28.5 (92-93.5)	19.9	Not tested, bag sample
F3-9-1	31.1-31.6 (102-103.5)	21.2	Not tested, bag sample

ATTERBERG LIMITS (PLASTICITY INDEX) TESTS

To assist in classifying the soils, four (4) Atterberg Limits tests were performed on selected samples. These tests were performed in accordance with ASTM D4318. The results are presented on Plate A-3 and are also indicated on the Log of Borings.

GRADATION ANALYSIS

Gradation analyses (ASTM D422) were performed on selected samples using both the sieve and hydrometer methods to evaluate grain size distribution. Eleven (11) sieve tests and four (4) hydrometer tests were performed on samples recovered from the project area. Hydrometer tests are used to evaluate the grain size distribution of particles smaller than the #200 U.S. Standard Sieve size. Where necessary, a sieve analysis was performed on the samples to sort the larger particles prior to hydrometer testing. Results of sieve and hydrometer tests are presented on Plate A4.1 through A4.10. Gradation analyses followed the test procedure outlined in ASTM D422.

UNCONFINED COMPRESSION STRENGTH TESTS

Three (3) cohesive samples were tested in unconfined compression strength tests following ASTM designation D2166. The unconfined compression test results are tabulated below.

Boring-Sample #	Depth, meters (feet	Unconfined Compressive Strength, psf (kg/cm^2)
F1-10-2	14.8-15.3 (48.5-50)	1516 (0.76)
F2-3-1	14.9-15.4 (49-50.5)	158 (0.08)
F2-3-2	14.9-15.4 (49-50.5)	105 (0.05)

Appendix A - Soil Sampling and Laboratory Testing Data

LIST OF FIGURES AND TABLES

The following plates and tables are attached as part of Appendix A:

Project: Fort Kamehameha Outfall Replacement EIS
Project Location: Honolulu, Oahu, Hawaii
Project Number: HI74

Log of Boring KEY
Sheet 1 of 1

Date(s) Drilled		Logged By		Checked By	
Drilling Method		Drill Bit Size/Type		Total Depth Drilled (feet)	30.0
Drill Rig Type		Drilled By		Hammer Weight/ Drop (lbs/in.)	
Apparent Downhole Groundwater Depth				Surface Elevation (feet)	
Coordinates				Elevation Datum	

Depth, feet	SAMPLES: Type	Number	Sampling Resistance	Recovery	Pocket Pen., ksf	Graphic Log	MATERIAL DESCRIPTION and other remarks	FIELD NOTES
0							**Sampler Symbols**	
							Standard Penetration Test (SPT)	
5							3-inch diameter split sampler	
10							**Strata Symbols**	
							Sand	
							Clay	
15							Silt	
							Silty gravel	
							Gravel	
20							Gravel and coral pieces	
							Clayey gravel	
25							**Laboratory Tests**	
							LL - Liquid Limit PI - Plasticity Index SA - Sieve Analysis Hyd - Hydrometer Analysis UC - Unconfined Compression Strength	
30								

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PLATE A-1

Project: Fort Kamehameha Outfall Replacement EIS
Project Location: Honolulu, Oahu, Hawaii
Project Number: HI74

Log of Boring F1

Sheet 1 of 3

Date(s) Drilled	3/17/97	Logged By	A. Dean	Checked By	J. Kwong
Drilling Method	Rotary wash	Drill Bit Size/Type	4" diamond bit	Total Depth Drilled (feet)	70.0
Drill Rig Type	Mobile B-53	Drilled By	HTB	Hammer Weight/ Drop (lbs/in.)	140/30
Apparent Downhole Groundwater Depth	2.5' b.g.s.			Surface Elevation (feet)	3
Coordinates				Elevation Datum	MSL

Depth, feet	Sample Number	Sampling Resistance	Recovery	Pocket Pen., ksf	MATERIAL DESCRIPTION and other remarks	FIELD NOTES
0					BEACH DEPOSITS Loose, moist, gray, poorly graded coralline beach sand (SP)	Auger to 6.5'
3					BEACH DEPOSITS Loose, wet, gray, poorly graded silty sand (SM) with shell fragments	Strong hydrocarbon odor
5	1	8				W% = 34
6.5						Wash boring from 6.5'
7.5					REEF DETRITUS Very loose, wet, light gray, poorly graded coralline gravel (GP) with coralline sand	
9	2	10				SA
12.5					BEACH DEPOSITS Medium dense, wet, white, silty coralline fine sand (SM) with patches of white poorly graded sand and gravel-sized cemented fine sand fragments	
14	3	25				
15.5					BEACH DEPOSITS Medium dense, wet, white, poorly graded coralline sand with silt (SP-SM); and shell fragments, and some sand and gravel-sized cemented sand nodules	
19	4	42				SA
22					Becomes loose, silty sand (SM) with trace coralline gravel	
24	5	8				SA & Hyd
26					BEACH DEPOSITS Loose, wet, yellowish brown, silty sand (SM) with gravel-sized cemented fine sand fragments (GM) with fine sand	
29	6	17				SA
30						

PLATE A-1.1

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Project: Fort Kamehameha Outfall Replacement EIS
Project Location: Honolulu, Oahu, Hawaii
Project Number: HI74

Log of Boring F1

Sheet 2 of 3

Depth, feet	Sample Number	Sampling Resistance	Recovery	Pocket Pen., ksf	MATERIAL DESCRIPTION and other remarks	FIELD NOTES
30						
34	7	6				
38					Wet, yellowish brown, well graded coralline sand with silt and coralline gravel	
39	8	10				
41					BEACH DEPOSITS Very loose, wet, brown, silty gravel-sized angular fragments of cemented fine sand in matrix (SM), mottled black and yellowish	
44	9	2				UC = 1516 psf LL = 61, PI = 27
47					OLD ESTUARINE DEPOSITS Stiff, wet, brown, high plasticity silt (MH) with trace coralline sand and shell fragments	
49	10	29		2		
52					Becomes medium stiff to stiff, with patches of red sand and trace gravel	
54	11	8				LL = 57, PI = 18
57					BEACH DEPOSITS Very dense, wet, brown, silty sand (SM) with zones of calcareous sandstone and tuffaceous gravel and conglomerate	
59	12	80/5"				
62.5					VOLCANIC TUFF Wet, brown, moderately weathered, bedded, friable to hard, volcanic tuff, with silty sand (SM) and sandy silt (ML) layers	
65						

PLATE A-1.1

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Project: Fort Kamehameha Outfall Replacement EIS
Project Location: Honolulu, Oahu, Hawaii
Project Number: HI74

Log of Boring F1

Sheet 3 of 3

Depth, feet	Samples: Type	Samples: Number	Samples: Sampling Resistance	Samples: Recovery	Pocket Pen., ksf	Graphic Log	MATERIAL DESCRIPTION and other remarks	FIELD NOTES
65								
70	■	13	87					
							Bottom of boring at 70 feet	
75								
80								
85								
90								
95								
100								

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PLATE A-1.1

Project: Fort Kamehameha Outfall Replacement EIS
Project Location: Honolulu, Oahu, Hawaii
Project Number: HI74

Log of Boring F2

Sheet 1 of 4

Date(s) Drilled	3/18/97	Logged By	A. Dean	Checked By	J. Kwong
Drilling Method	Rotary wash	Drill Bit Size/Type	4" diamond bit	Total Depth Drilled (feet)	120.5
Drill Rig Type	Mobile B-53	Drilled By	HTB	Hammer Weight/ Drop (lbs/in.)	140/30
Apparent Downhole Groundwater Depth	0'			Surface Elevation (feet)	0
Coordinates				Elevation Datum	MSL

Depth, feet	Samples: Type	Samples: Number	Samples: Sampling Resistance	Samples: Recovery	Pocket Pen., ksf	Graphic Log	MATERIAL DESCRIPTION and other remarks	FIELD NOTES
0							Water Column	
5								
10								
15								
20								
25								
30								

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PLATE A-1.2

Project: Fort Kamehameha Outfall Replacement EIS Project Location: Honolulu, Oahu, Hawaii Project Number: HI74	Log of Boring F2 Sheet 2 of 4

Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery	Pocket Pen., ksf	Graphic Log	MATERIAL DESCRIPTION and other remarks	FIELD NOTES
30								
35								
40							Mudline	
		1	0				RECENT MARINE SEDIMENTS Very loose, wet, gray, silty sand (SM)	
45		2	0				RECENT MARINE SEDIMENTS Very soft, wet, light blue gray, low plasticity silt (ML), with layers of sandy silt to silty sand (ML-SM)	LL=46, PI=19
50		3	0				With shell fragments	Strong organic odor UC=158 psf UC=105 psf
		4	7				MARINE SEDIMENTS Loose, wet, gray, silty poorly graded sand (SP) with some shell fragments and black sand	Organic odor
55		5	14				REEF DETRITUS Loose, wet, gray, gravel and cobble size coral fragments (GP-GM), in a silty sand matrix	Organic odor SA & Hyd
60		6	6					Organic odor
							MARINE SEDIMENTS Very loose, wet, gray, silty very fine sand (SM), with trace coralline sands	
65		7	1				Shell and coral fragments	PI

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PLATE A-1.2

Project: Fort Kamehameha Outfall Replacement EIS Project Location: Honolulu, Oahu, Hawaii Project Number: HI74	Log of Boring F2 Sheet 3 of 4

Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery	Pocket Pen., ksf	Graphic Log	MATERIAL DESCRIPTION and other remarks	FIELD NOTES
65								Organic odor
70		8	0					Organic odor
75		9	0				With rare thin zones of dark gray, silty sand	Organic odor
80		10	0					
85		11	11				Becomes very loose to loose with shell fragments	Slight organic odor
								Slight organic odor
90		12	0				Very loose, sand fraction increases	
95		13	7				Becomes lighter in color	Slight organic odor
								Slight organic odor
100		14	1					

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PLATE A-1.2

Project: Fort Kamehameha Outfall Replacement EIS
Project Location: Honolulu, Oahu, Hawaii
Project Number: HI74

Log of Boring F2

Sheet 4 of 4

Depth, feet	Type	Number	Sampling Resistance	Recovery	Pocket Pen., ksf	Graphic Log	MATERIAL DESCRIPTION and other remarks	FIELD NOTES
100								
105							MARINE SEDIMENTS Medium dense, wet, gray, silty very fine sand (SM), with weakly cemented zones, trace shell fragments	Driller noted harder drilling at 106'
110		15	44					Slight organic odor
115							MARINE SEDIMENTS Very loose, wet, gray, interbedded medium sand (SP) and silty sand to sandy silt (SM-ML)	
120		16	3				Fine silty sand with layers of clayey sand with silt	Slight organic odor
							Bottom of boring at 120.5 feet	
125								
130								
135								

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PLATE A-1.2

Project: Fort Kamehameha Outfall Replacement EIS
Project Location: Honolulu, Oahu, Hawaii
Project Number: HI74

Log of Boring F3

Sheet 1 of 4

Date(s) Drilled	3/17/97	Logged By	A. Dean	Checked By	J. Kwong
Drilling Method	Rotary wash	Drill Bit Size/Type	4" diamond bit	Total Depth Drilled (feet)	115.5
Drill Rig Type	Mobile B-53	Drilled By	Donald Alpla	Hammer Weight/ Drop (lbs/in.)	140/30
Apparent Downhole Groundwater Depth	Sea level			Surface Elevation (feet)	0
Coordinates				Elevation Datum	MSL

Depth, feet	Type	Number	Sampling Resistance	Recovery	Pocket Pen., ksf	Graphic Log	MATERIAL DESCRIPTION and other remarks	FIELD NOTES
0								
5								
10								
15								
20							Mudline	
25		1	0				REEF DETRITUS Loose, wet, white, gravel-sized finger coral fragments (GP)	
30								

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PLATE A-1.3

Project: Fort Kamehameha Outfall Replacement EIS
Project Location: Honolulu, Oahu, Hawaii
Project Number: HI74

Log of Boring F3

Sheet 2 of 4

Depth, feet	Type	Number	Sampling Resistance	Recovery	Pocket Pen., ksf	MATERIAL DESCRIPTION and other remarks	FIELD NOTES
30							
		2	17				
35							
						With gray, fine sand and shell fragments	
40							
		3	34			MARINE SEDIMENTS Medium dense, wet, gray, poorly graded fine sand (SP) with silt and some hard gravel size white coral fragments	
45							
50						MARINE SEDIMENTS Very soft to soft, wet, gray, lean silt (ML) with coralline sand	
		4	3				LL=37, PI=7
55							
60							
		5	101			REEF DETRITUS Very dense, wet, gray, coralline gravel (GW) (coral fragments) with coralline sand, cobble and shell fragments, trace black sand and silt	
65							

Project: Fort Kamehameha Outfall Replacement EIS
Project Location: Honolulu, Oahu, Hawaii
Project Number: HI74

Log of Boring F3

Sheet 3 of 4

Depth, feet	Type	Number	Sampling Resistance	Recovery	Pocket Pen., ksf	MATERIAL DESCRIPTION and other remarks	FIELD NOTES
65						Hard zone (probable coralline cobbles and boulders or cemented coralline ledge)	
70							
		6	59				SA
75							
						BEACH DEPOSITS Very dense, wet, light brown, subangular to subrounded poorly graded fine to medium coralline sand (SP-SM) with silt	
80							
		7	88			Grades to coarse	
						REEF DETRITUS Very dense, wet, light gray to white, silty coralline gravel (GM) with coralline sand and cobbles	
85							
						Becomes light brown, with cemented zones	
90							
		8	70				SA & Hyd
95							
						REEF DETRITUS Dense, wet, light brown, well graded gravel with silt and sand (GW-GM) and pockets of light brown, high plasticity silt	
100							

Project: Fort Kamehameha Outfall Replacement EIS
Project Location: Honolulu, Oahu, Hawaii
Project Number: HI74

Log of Boring F3

Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery	Pocket Pen., ksf	Graphic Log	MATERIAL DESCRIPTION and other remarks	FIELD NOTES
100								
		9	42					SA
105								
							Becomes very dense, wet, well graded sandy gravel (GW) with trace clay	
110								
		10	52					SA
115								
							Bottom of boring at 115.5 feet	
120								
125								
130								
135								

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Project: Fort Kamehameha Outfall Replacement EIS
Project Location: Honolulu, Oahu, Hawaii
Project Number: HI74

Log of Boring F3A

Date(s) Drilled	3/19/97	Logged By	A. Dean	Checked By	J. Kwong
Drilling Method	Rotary wash	Drill Bit Size/Type	4" diamond bit	Total Depth Drilled (feet)	28.5
Drill Rig Type	Mobile B-53	Drilled By	Donald Alpia	Hammer Weight/ Drop (lbs/in.)	140/30
Apparent Downhole Groundwater Depth	Sea level			Surface Elevation (feet)	0
Coordinates				Elevation Datum	MSL

Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery	Pocket Pen., ksf	Graphic Log	MATERIAL DESCRIPTION and other remarks	FIELD NOTES
0								
5								
10								
15								
20								
		1	0				Mudline RECENT MARINE SEDIMENTS Very loose, wet, gray, coralline sand (SP)	Boring terminated due to wave conditions
25								
		2	96/8"				REEF DETRITUS Very dense, wet, gray, gravel and cobble size coral fragments and sand lenses (GP) Bottom of boring at 28.5 feet.	
30								

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SOIL CLASSIFICATION CHART

Major Divisions			Symbol	Typical Names	Other Criteria
COARSE GRAINED SOILS More than 50% of material larger than No. 200 sieve size	Gravels More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravel Little or no fines (<5%)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines	Cu>4 and 1<=Cc<=3
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines	Not meeting Cu and Cc criteria for GW
		Gravels with Fines Appreciable amount of fines (>12%)	GM	Silty gravels, gravel-sand-silt mixtures	Atterberg limit below A-line or PI <4
			GC	Clayey gravels, gravel-sand-clay mixtures	Atterberg limit above A-line with PI >7
	Sands More than 50% of coarse fraction passing No. 4 sieve	Clean Sands Little or no fines (<5%)	SW	Well-graded sands, gravelly sands, little or no fines	Cu>6 and 1<=Cc<=3
			SP	Poorly graded sands, gravelly sands, little or no fines	Not meeting Cu and Cc criteria for SW
		Sands with Fines Appreciable amount of fines (>12%)	SM	Silty sands, sand-silt mixture	Atterberg limit below A-line, or PI <4
			SC	Clayey sands, sand-clay mixture	Atterberg limit above A-line with PI>7
FINE GRAINED SOILS More than 50% of material smaller than No. 200 sieve size	Silts and Clays Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	Atterberg limit below A-line
			CL	Inorganic clays of low to medium plasticity, gravely clays, sandy clays, lean clay	Atterberg limit above A-line
			OL	Organic silts and organic silty clays f low plasticity	Atterberg limit below A-line
	Silts and Clays Liquid limit larger than 50%		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Atterberg limit below A-line
			CH	Inorganic clays of high plasticity, fat clays	Atterberg limit above A-line
			OH	Organic clays of high plasticity, organic silts	Atterberg limit below A-line
HIGHLY ORGANIC SOILS			Pt	Peat and other highly organic soils	

Notes:

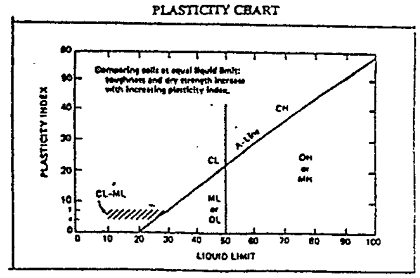
1 Cu = D60/D10, Cc = (D30)^2/(D60 x D10) where D60, D30 and D10 are diameters associated with 60%, 30%, and 10% smaller in gradation curves.
2 Dual symbols are used to indicate borderline classifications such as GP/GC.

GRADATION CHART

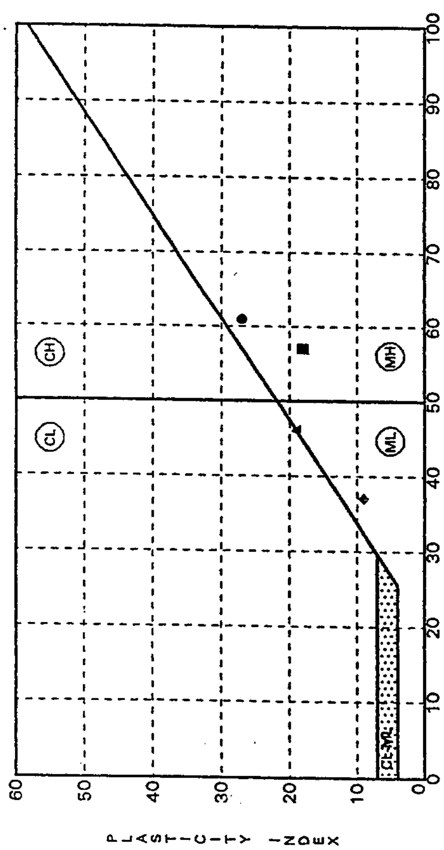
Soil Fraction	Size Range			
	Lower Limit		Upper Limit	
	Millimeters	Sieve	Millimeters	Sieve
Boulders	304.8	12*	914.4	36*
Cobbles	76.2	3*	304.8	12*
Gravel				
Coarse	19.1	3/4*	76.2	3*
Fine	4.76	4**	19.1	3/4*
Sand				
Coarse	2	10**	4.76	4**
Medium	0.42	40**	2	10**
Fine	0.074	200**	0.42	40**
Fines			0.074	200**

* U.S. standard sieve opening in inches
** U.S. standard sieve number

PLASTICITY CHART



Woodward-Clyde Federal Services	UNIFIED SOIL CLASSIFICATION SYSTEM	PLATE A- 2



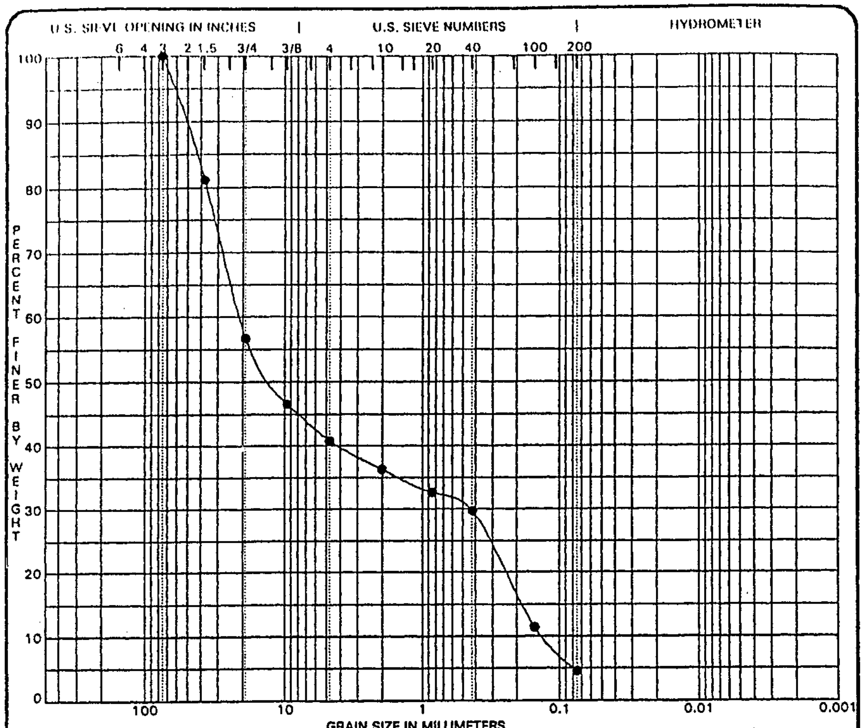
	Boring	Depth (m)	LL	PL	PI	Fines	Classification
●	F1	14.8	61	34	27		
■	F1	15.9	57	39	18		
▲	F2	13.4	46	27	19		
◆	F3	16.3	37	28	9		

PROJECT Preliminary Geotechnical Evaluation for WWTP at Fort Kamehameha, Ocean Outfall Extension, Pearl Harbor, Oahu, Hawaii NO. HI74

ATTERBERG LIMITS

Woodward-Clyde
Honolulu, Hawaii

PLATE A-3



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Boring	Depth (m)	Classification	MC%	LL	PL	PI	Cc	Cu
●	F1	2.7	Poorly Graded Gravel with Sand GP					0.08	160.2

	Boring	Depth (m)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	F1	2.7	75.00	20.83	0.457	0.1301	59.2	36.2	4.6	

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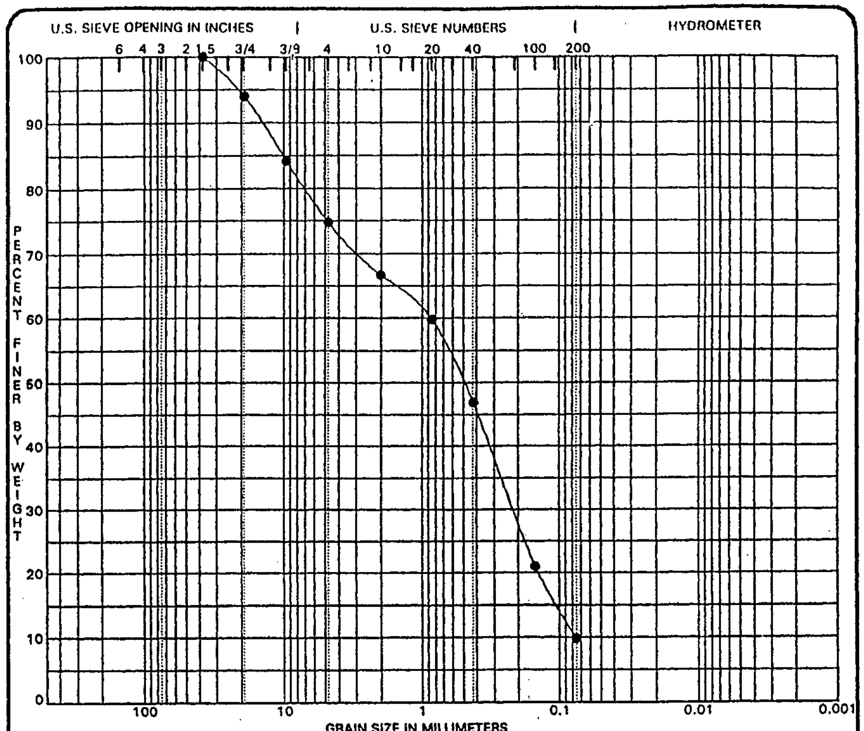
GRADATION CURVES

Woodward-Clyde
Honolulu, Hawaii

PLATE A-4.1



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Boring	Depth (m)	Classification	MC%	LL	PL	PI	Cc	Cu
●	F1	5.6	Poorly Graded Sand with Silt SP-SM	38				0.70	11.5

	Boring	Depth (m)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	F1	5.6	37.50	0.87	0.215	0.0759	25.3	64.9	9.8	

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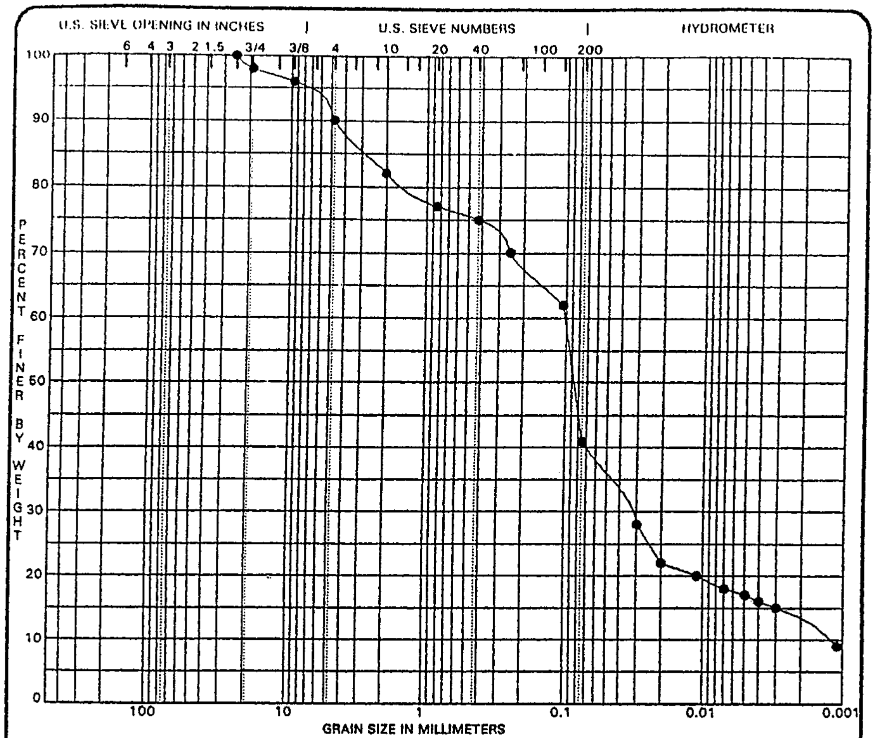
GRADATION CURVES

Woodward-Clyde
Honolulu, Hawaii

PLATE A-4.2



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Boring	Depth (m)	Classification	MC%	LL	PL	PI	Cc	Cu
●	F1	7.2	Silty Sand SM						

	Boring	Depth (m)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	F1	7.2	25.00	0.10	0.035	0.0013	10.0	49.0	24.0	17.0

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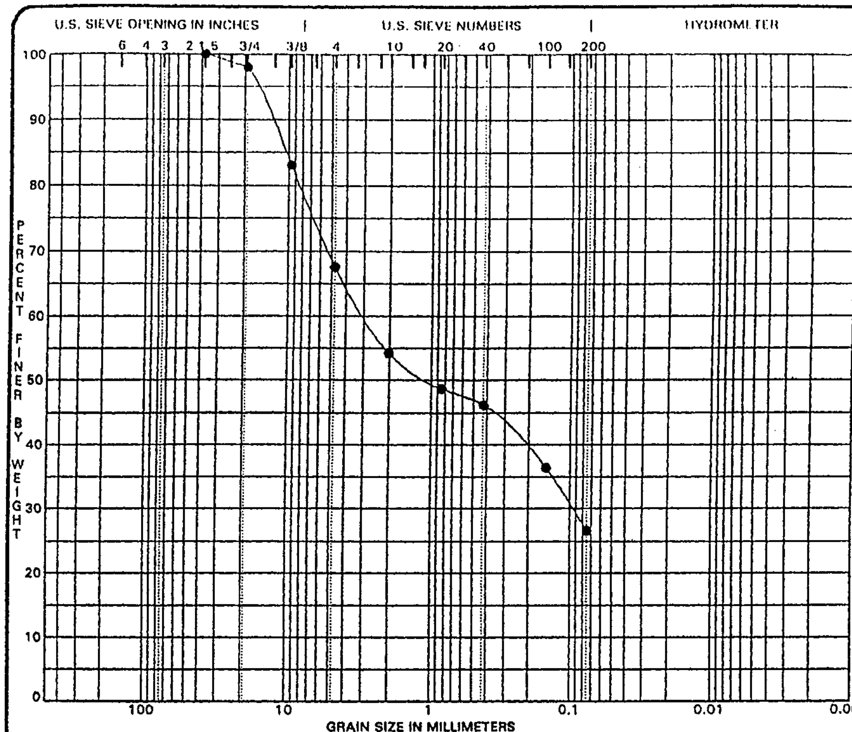
GRADATION CURVES

Woodward-Clyde
Honolulu, Hawaii

PLATE A-4.3



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Boring	Depth (m)	Classification	MC%	LL	PL	PI	Cc	Cu
●	F1	8.7	Silty Sand with Gravel SM	44					

	Boring	Depth (m)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	F1	8.7	37.50	2.92	0.095		32.5	40.9	26.6	

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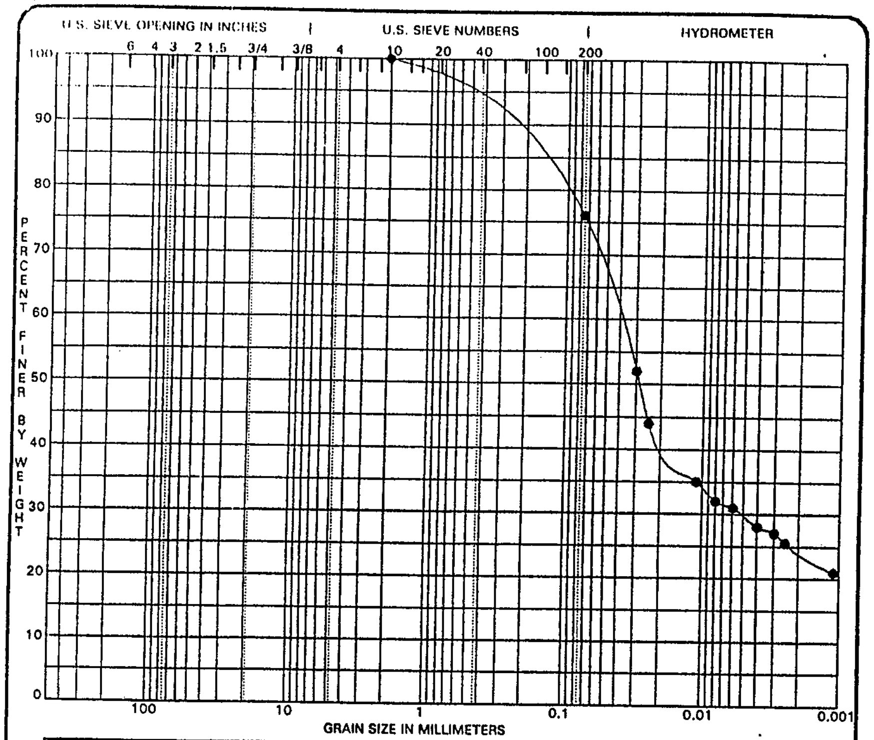
GRADATION CURVES

Woodward-Clyde
Honolulu, Hawaii

PLATE A-4.4



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Boring	Depth (m)	Classification	MC%	LL	PL	PI	Cc	Cu
●	F2	15.0	Sandy Silt ML						

	Boring	Depth (m)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	F2	15.0	2.00	0.04	0.005		0.0	24.0	46.3	29.7

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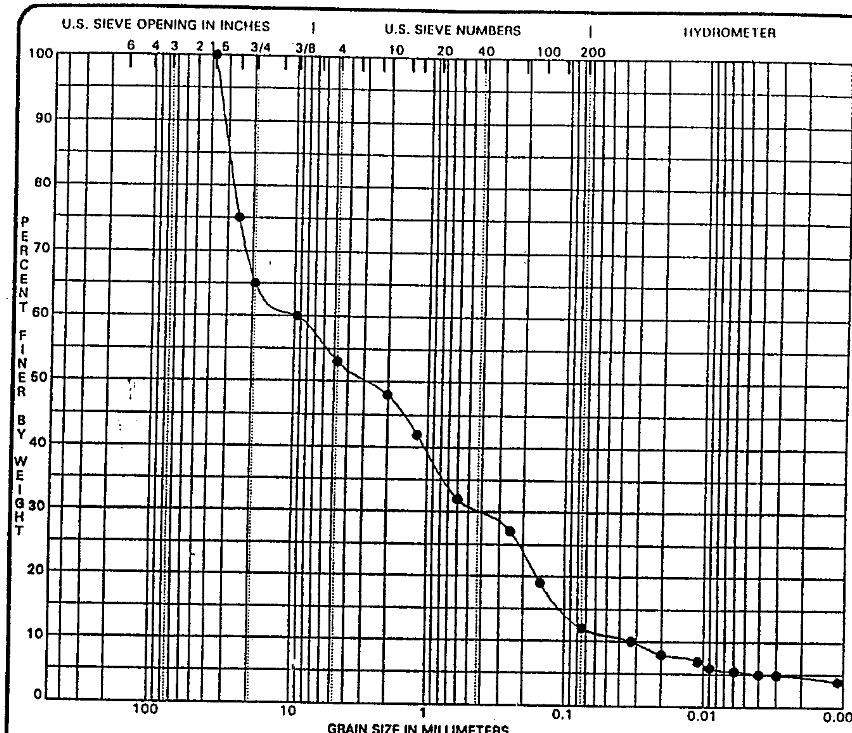
GRADATION CURVES

Woodward-Clyde
Honolulu, Hawaii

PLATE A-4.5



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Boring	Depth (m)	Classification	MC%	LL	PL	PI	Cc	Cu
●	F2	16.5	Poorly Graded Gravel with Silt and Sand GM					0.27	135.7

	Boring	Depth (m)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	F2	16.5	37.50	9.50	0.423	0.0330	47.0	41.0	6.7	5.3

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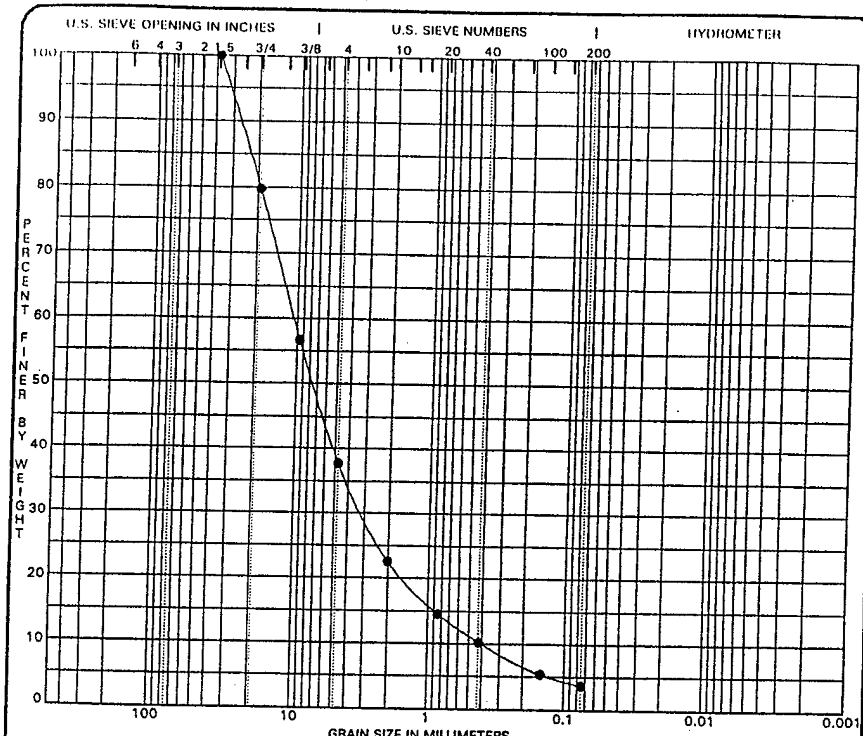
GRADATION CURVES

Woodward-Clyde
Honolulu, Hawaii

PLATE A-4.6



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Boring	Depth (m)	Classification	MC%	LL	PL	PI	Cc	Cu
●	F3	22.0	Well Graded Gravel with Sand GW					2.20	25.8

	Boring	Depth (m)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	F3	22.0	37.50	10.49	3.065	0.4070	62.3	34.0	3.7	

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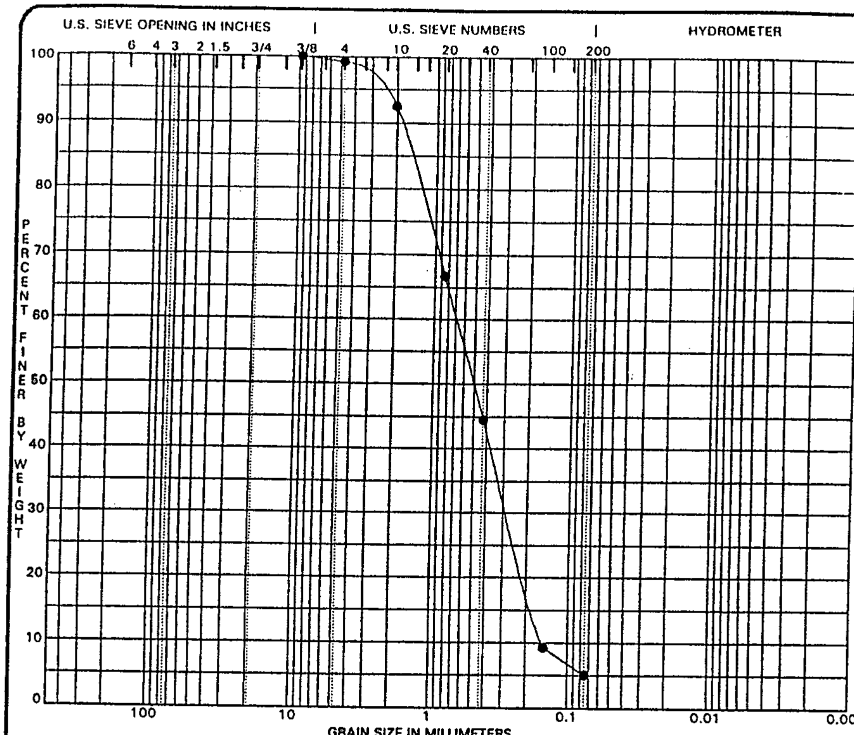
GRADATION CURVES

Woodward-Clyde
Honolulu, Hawaii

PLATE A-4.7



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Boring	Depth (m)	Classification	MC%	LL	PL	PI	Cc	Cu
●	F3	25.0	Poorly Graded Sand with Silt SP-SM	28				0.73	4.5

	Boring	Depth (m)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	F3	25.0	9.50	0.69	0.277	0.1531	0.8	94.1	5.1	

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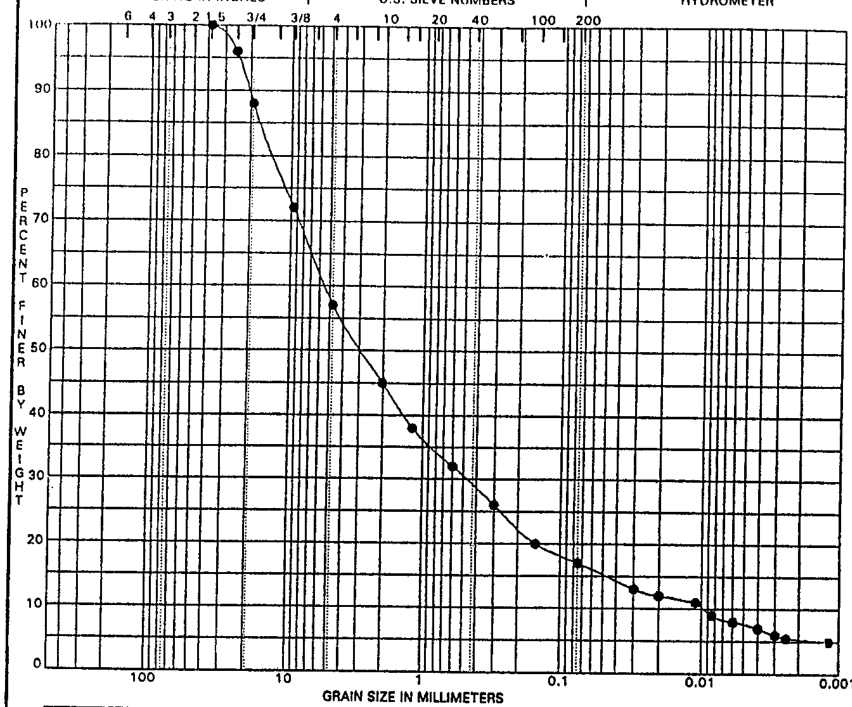
GRADATION CURVES

Woodward-Clyde
Honolulu, Hawaii

PLATE A-4.8



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Boring	Depth (m)	Classification	MC%	LL	PL	PI	Cc	Cu
●	F3	28.0	Silty Gravel with Sand GM						

	Boring	Depth (m)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	F3	28.0	37.50	5.46	0.476	0.0097	43.0	40.0	9.4	7.6

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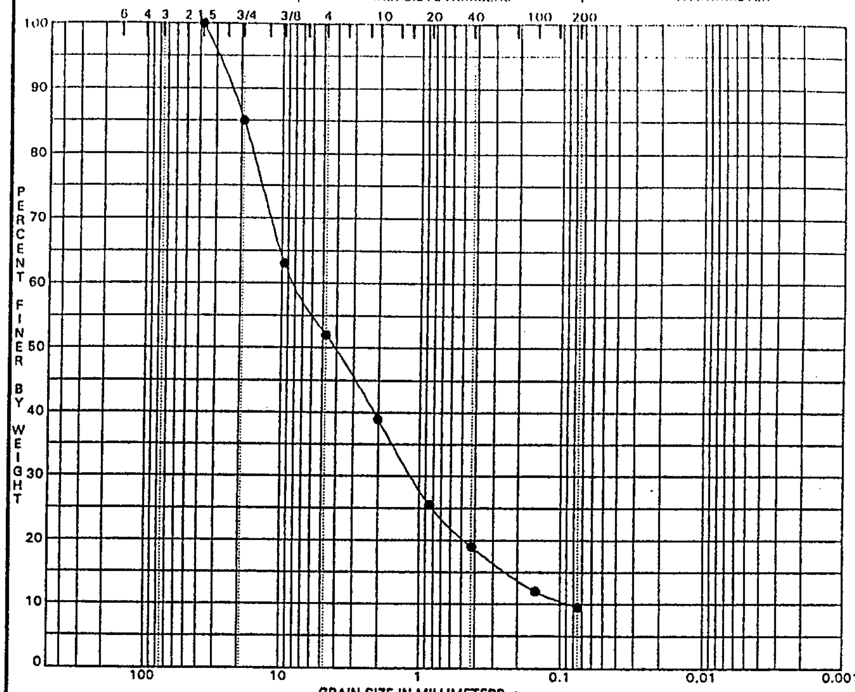
NO. HI74

GRADATION CURVES

Woodward-Clyde
Honolulu, Hawaii

PLATE A-4.9



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Boring	Depth (m)	Classification	MC%	LL	PL	PI	Cc	Cu
●	F3	31.1	Well Graded Gravel with Silt and Sand GW-GM	21				1.89	91.3

	Boring	Depth (m)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay.
●	F3	31.1	37.50	7.86	1.131	0.0862	48.0	42.5	9.5	

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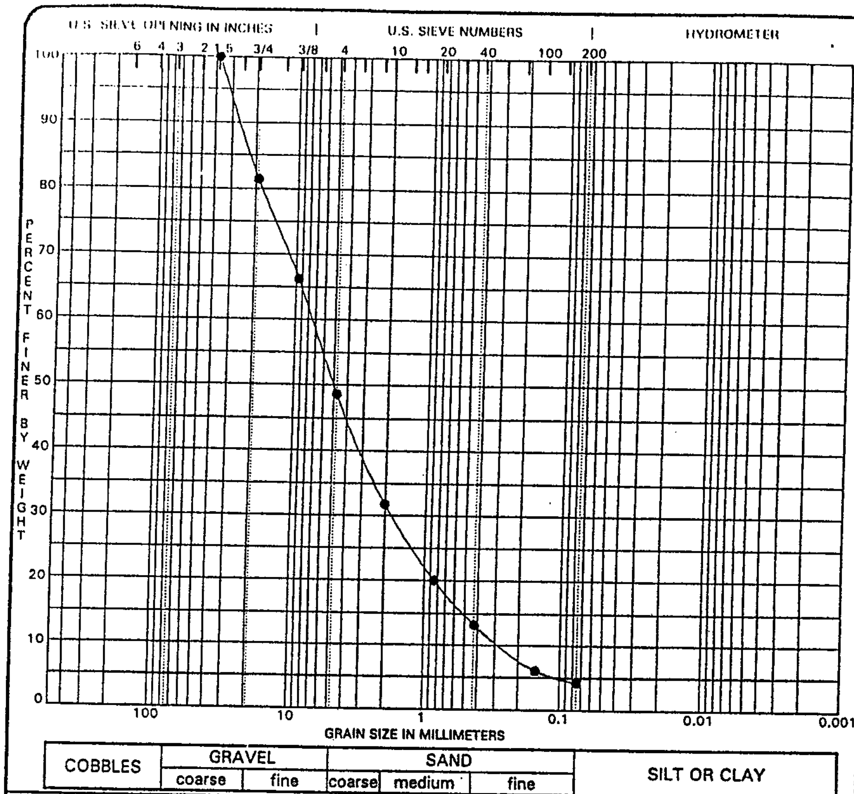
GRADATION CURVES

Woodward-Clyde
Honolulu, Hawaii

PLATE A-4.10



	Boring	Depth (m)	Classification	MC%	LL	PL	PI	Cc	Cu
●	F3	34.1	Well Graded Gravel with Sand GW					1.56	28.0

	Boring	Depth (m)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	F3	34.1	37.50	7.44	1.755	0.2658	51.4	44.4	4.2	

PROJECT Preliminary Geotechnical Evaluation for Fort Kamehameha WWTP Ocean Outfall Extension, Pearl Harbor, Oahu, Hawaii

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GRADATION CURVES

Woodward-Clyde
Honolulu, Hawaii

PLATE A-4.11

Appendix B - Results of Marine Seismic Refraction Survey Performed by Sea Engineering, Inc.

4.0 BATHYMETRY AND BOTTOM CONDITIONS

4.1 Bathymetry

General bathymetric information for the area seaward of the Pearl Harbor entrance channel is available on the National Ocean Service (NOS) chart 19362 at a scale of 1 to 20,000. More detailed information was required for the outfall planning, and a hydrographic survey was conducted as part of the oceanographic study. The results are shown in Figure 4-1.

The primary nearshore feature of the project area is a 1,220 m wide shallow fringing reef flat between the entrance channel and the Hickam small boat harbor. The reef is bounded on the west by the Pearl Harbor entrance channel and on the east by the Reef Runway. The Pearl Harbor entrance the channel has been steeply cut through the shallow reef flat to a depth of 15 m.

Seaward of the channel entrance the bathymetry is dominated by a large embayment, approximately 1,220 m across, that begins just seaward of the entrance channel at approximately the 21 m depth. This embayment can be clearly seen on Figure 4-1. Like many bathymetric features of O'ahu, the embayment was probably formed during a period of lower sea level. A secondary channel enters the embayment immediately west of the Pearl Harbor entrance channel.

The slope of the offshore bathymetry is highly variable, and is shown in more detail in Figure 4-2. There is a noticeable steepening of the ocean bottom between the 26 and 42 m contours, and also between the 54 and 70 m contours.

Seaward of the fringing reef the bottom slopes gently (1V:20H) between 8 and 18 m, and is composed of coralline reef rock that is highly eroded in places and grooved by numerous channels. Between 18 and 26 m, the bottom slopes at approximately 1V:35H. Beyond the 20 m depth the bottom is primarily sand. Between 28 and 42 m, the bottom slope steepens to 1V:6H. SEI used a jet probe on this slope at a depth of 29 m and found sand greater than 10 m thick. The slope flattens to 1V:14H between the 42 and 54 m depth, and then increases to 1V:8H between the 54 and 70 m depth.

4.2 Geologic Structure

Diving surveys of the project area indicated that the bottom seaward of the 20 m contour consisted of an extensive sand deposit. Since this feature presented an important design consideration, SEI obtained additional bottom and sub-bottom information by completing

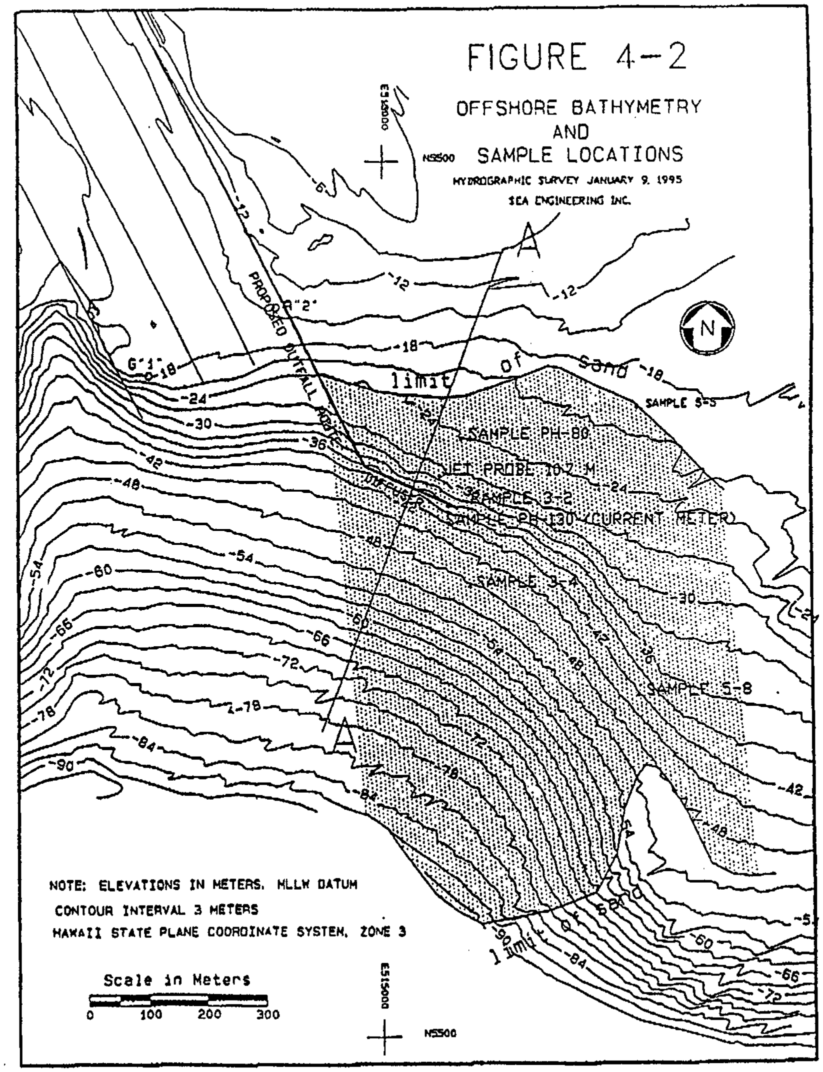


FIGURE 4-2
OFFSHORE BATHYMETRY AND SAMPLE LOCATIONS
HYDROGRAPHIC SURVEY JANUARY 9, 1995
SEA ENGINEERING INC.

a high resolution geophysical survey. This survey and provided much more extensive information than the diving reconnaissance and the water jet probing.

Six survey lines were mapped with a geophysical sub-bottom profiling system that had been recently developed specifically for application to Hawaiian bottom types (Sea Engineering, Inc., et al, 1995). Figure 4-2 shows the aerial extent of the sand as determined by the geophysical survey. The deposit extends well beyond the limits of the geophysical survey. The diving observations indicated that the deposit extends west across the entrance channel, with the shallow boundary approximately following the 22 m contour to at least the west border of Figure 4-2.

An actual geophysical survey record, taken close to profile line A - A', is shown in Figure 4-3. A schematic geologic cross-section along A -A', interpreted from Figure 4-3, is shown in Figure 4-4.

Interpretation of the geophysical records correlated with direct observations was used to develop the isopach map of sand thickness shown in Figure 4-5. The sand is at least 3 m thick over much of the project area, with large areas of sand 6 m thick and occasional thicknesses over 10 m.

Sediment samples were collected at the stations shown on Figures 4-1 and 4-2. All samples were analyzed for grain size; two were additionally analyzed for chemical contamination. The sand at depths greater than 42 m is noticeably finer grained than the sand on the steep slope between the 28 and 42 m depths. There was also a thin layer of vegetative growth on the sand surface at the deeper sampling stations (Stations 5-8 and 3-4), indicative of at least short term stability. By contrast, hummocky terrain was observed at the 37 m depth near the eastern end of the mapped sand deposit. The hummocks were composed of patches of clean sand with no vegetation, and with a vertical relief of approximately 1.5 m between the peaks and valleys. The clean sand overlay sand with vegetative cover, indicating recent deposition. These observations were made in midsummer 1995, after a large south swell (5 m high breaking waves) impacted O'ahu's south shore.

4.3 Sediment Analysis

4.3.1 Grain Size Analysis

Sediment samples were obtained from six stations within the Pearl Harbor entrance channel (Stations 1 through 6, Figure 4-1), and from six stations in the sand deposit outside the channel (Stations Ph-80, PH-130, 3-2, 3-4, 5-5, and 5-8, Figure 4-2). Results of grain size analyses performed on the samples are contained in Appendix B.

A 1.2 m long coring device was used to obtain samples within the entrance channel. Penetration of the corer varied from zero at Station 6 to full penetration at Station 2. A surface sample only was recovered at Station 6. Station 1 had a refusal at 0.9 m, Station 4 had refusal at 0.15 m, and Station 5 had penetration of 0.6 m. The sediment from Stations 1 through 5 was composed of loosely packed (unconsolidated) very fine sand and silt. The sediment at Station 6 was hard packed (consolidated) sand, and was noticeably different from the soft sediment found at the other five stations.

The sediments at Stations 1 and 2 are predominately silt and clay sized, with approximately 75-percent of the sediment in the silt/clay classification. Sediments from Stations 3, 4, and 5 are well-sorted fine and very fine silty sands, with a silt and clay content of approximately 45-percent. The sample from Station 6 was well sorted medium-fine sand, with only a 7-percent silt and clay fraction.

The samples from the offshore sand deposit were collected by either driving 0.6 m long coring tubes into the sediment or by manually bagging surface sediment. Two samples each, sub-labeled "a" and "b", were collected at Stations PH-80, PH-130, and 3-2. Grain size analyses for these samples showed a trend toward finer sediments with increased water depth. The sediments are moderately well sorted to very well sorted and range in size from coarse sand at Station 3-2b to very fine sand at Station 3-4. Station 3-4 is the deepest sample, taken at the 48 m water depth, and is the only one with appreciable amounts of sediment in the silt and clay range (7.7%).

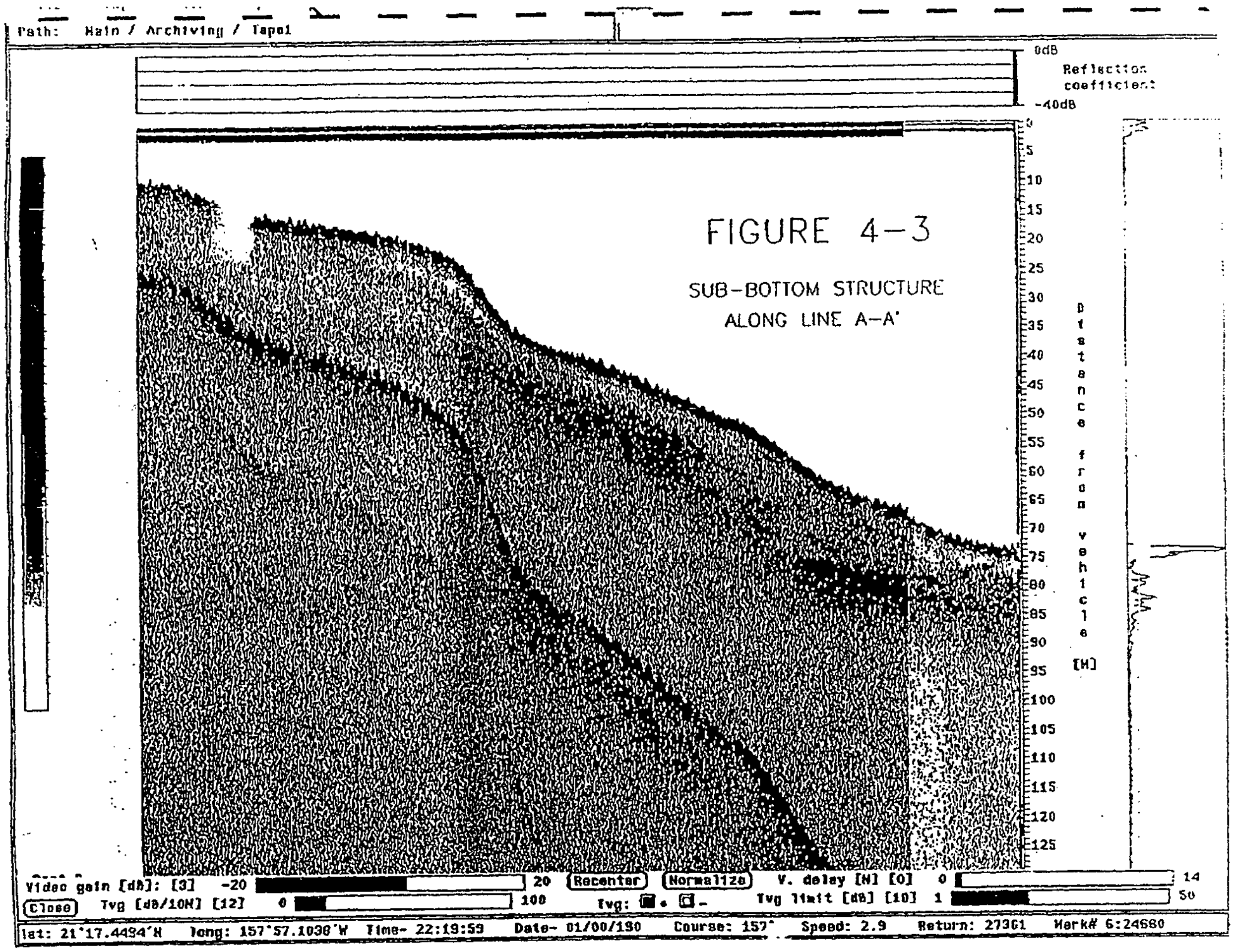
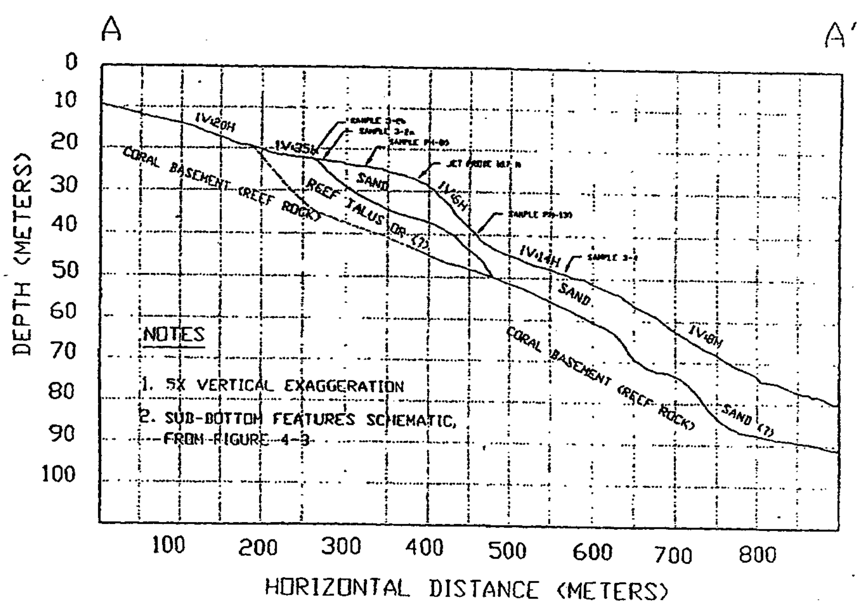


FIGURE 4-3

SUB-BOTTOM STRUCTURE ALONG LINE A-A'

FIGURE 4-4

OFFSHORE PROFILE: A - A'



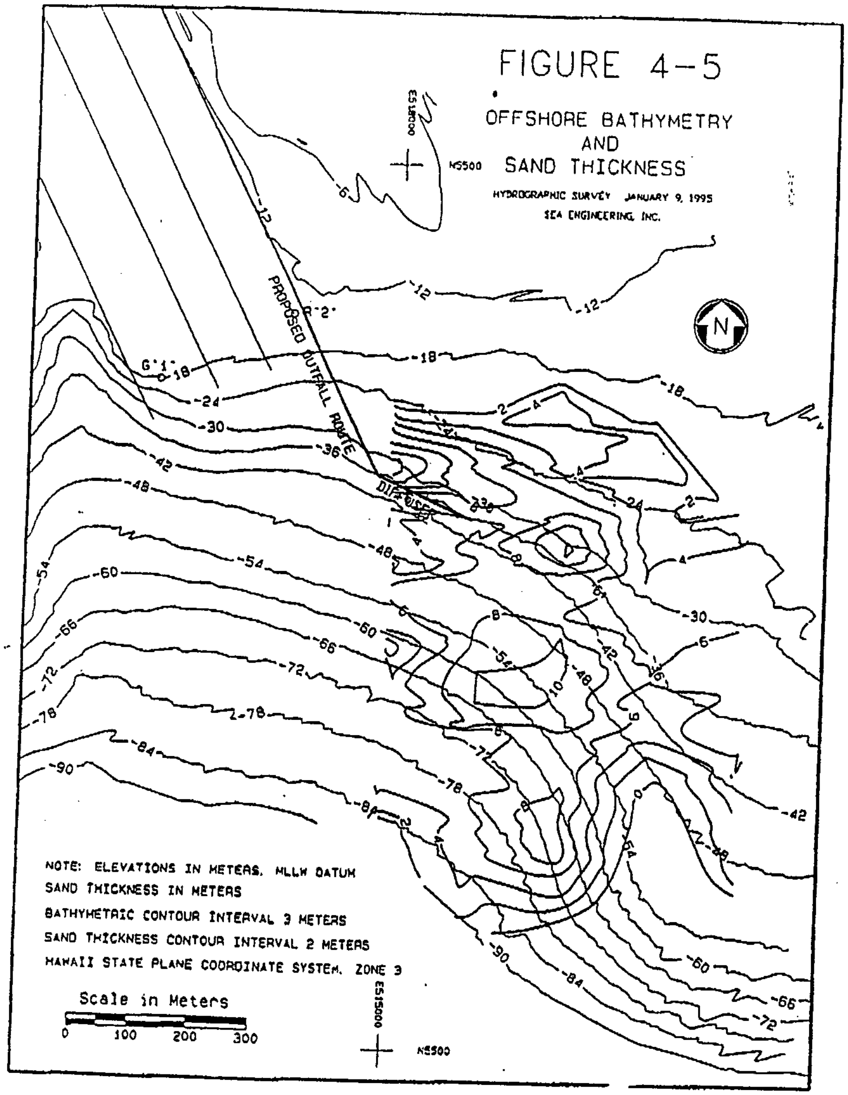


FIGURE 4-5
OFFSHORE BATHYMETRY AND SAND THICKNESS

Appendix V

Migratory Shorebird, Resident Waterbird and Seabird Survey of Fort Kamehameha Wetlands and Offshore Islets

MIGRATORY SHOREBIRD, RESIDENT WATERBIRD AND SEABIRD SURVEY OF FORT KAMEHAMEHA WETLANDS AND OFFSHORE ISLETS

Prep. for

Sea Engineering, Inc.

by

Phillip L. Bruner
Assistant Professor of Biology
Director, Museum of Natural History
BYU-Hawaii
Environmental Consultant - Faunal (Bird & Mammal) Surveys

11 December 1996

INTRODUCTION

The purpose of this report is to provide the findings of a two day (7 November, 3 December 1996) field survey of migratory shorebirds, resident waterbirds and seabirds observed at Fort Kamehameha wetlands and offshore islets (Fig. 1). In addition these data are compared with numbers of birds obtained on earlier surveys of this site (Bruner 1993abc, 1994abc; 1995).

METHODS

Survey methods on the 1993-1995 surveys and the two 1996 visits consisted of a complete walk-through and visual search of the offshore islets as well as coastal mangrove and <u>Batis</u> covered wetlands. Binoculars were used to identify and count birds. The surveys were conducted at low tide when birds had the greatest access to the habitat.

Common and scientific names used in this report follow those in Pratt et al. 1987 and Hawaii Audubon Society 1993. Weather during the two 1996 survey days was calm and partly cloudy.

RESULTS - DISCUSSION

Table One reports the kinds and numbers of birds recorded on the surveys. Four species of migratory shorebirds have been seen resting and foraging at this location. Only two species of seabirds were observed: Brown Booby (Sula leucogaster) and Common or Brown Noddy (Anous stolidus). They were observed foraging in the Pearl Harbor entrance channel and offshore (Fig. 1). The two native waterbird species present on some surveys were: Black-necked Stilt (Himantopus mexicanus) and Black-crowned Night Heron (Nycticorax nycticorax). The stilt is an endangered species. They forage in shallow water and will also rest on offshore islets. They would not likely nest in this area due to human disturbance and easy access of the habitat to predators. Black-crowned Night Heron also forage along shorelines and in shallow wetlands. All the night heron seen during these surveys were roosting in the mangrove trees fronting the Batis wetland. Black-crowned Night Heron are not listed as threatened or endangered. Other shorebirds such as Black-bellied Plover (Pluvialis squatarola) may also utilize this area between August and May.

Earlier bird studies in this area (Walker 1978, Berger 1989) looked at Fort Kamehameha and a number of sites around the reef runway and Keehi Lagoon. These earlier studies found many more stilts and night herons than presently occur in the area. This

likely reflects the overall reduction in waterbird populations due primarily to a decline in suitable and safe areas to nest. Foraging habitat does not appear to be a limiting factor. However, closer examination of the prey base may reveal that those areas that appear to be good foraging habitat may in fact be depauperate.

CONCLUSIONS AND RECOMMENDATION

The offshore islets and reef flats exposed at low tide serve as foraging and resting sites for migratory shorebirds and resident waterbirds. Seabirds occasionally utilize the Pearl Harbor entrance channel and nearby offshore waters for foraging.

Disturbance to the reef flats and offshore islets during the construction of the proposed outfall extension will temporarily displace the birds that would otherwise forage and rest at this location. However, given the relatively few birds noted at this location and the availability of nearby similar and undisturbed habitat the degree of impact to birds should be minimal.

Recommendation: Those areas of the reef and offshore islets that are disturbed by the construction should be cleaned up and restored to as near as possible to the conditions that preceeded the development.

TABLE 1

Summary of migratory shorebirds, resident waterbirds, and seabirds observed on nine surveys at Fort Kamehameha, Hickam AFB, Oahu, between April 1993 and December 1996.
* Species found on this 1996 survey.

COMMON NAME	SCIENTIFIC NAME	TOTAL NUMBER RECORDED (1993-1996)
*Pacific Golden-Plover	Pluvialis fulva	39
*Ruddy Turnstone	Arenaria interpres	19
*Sanderling	Calidris alba	9
*Wandering Tattler	Heteroscelus incanus	8
Black-necked Stilt	Himantopus mexicanus	2
*Black-crowned Night Heron	Nycticorax nycticorax	3
Brown Booby	Sula leucogaster	1
Common (Brown) Noddy	Anous stolidus	10±

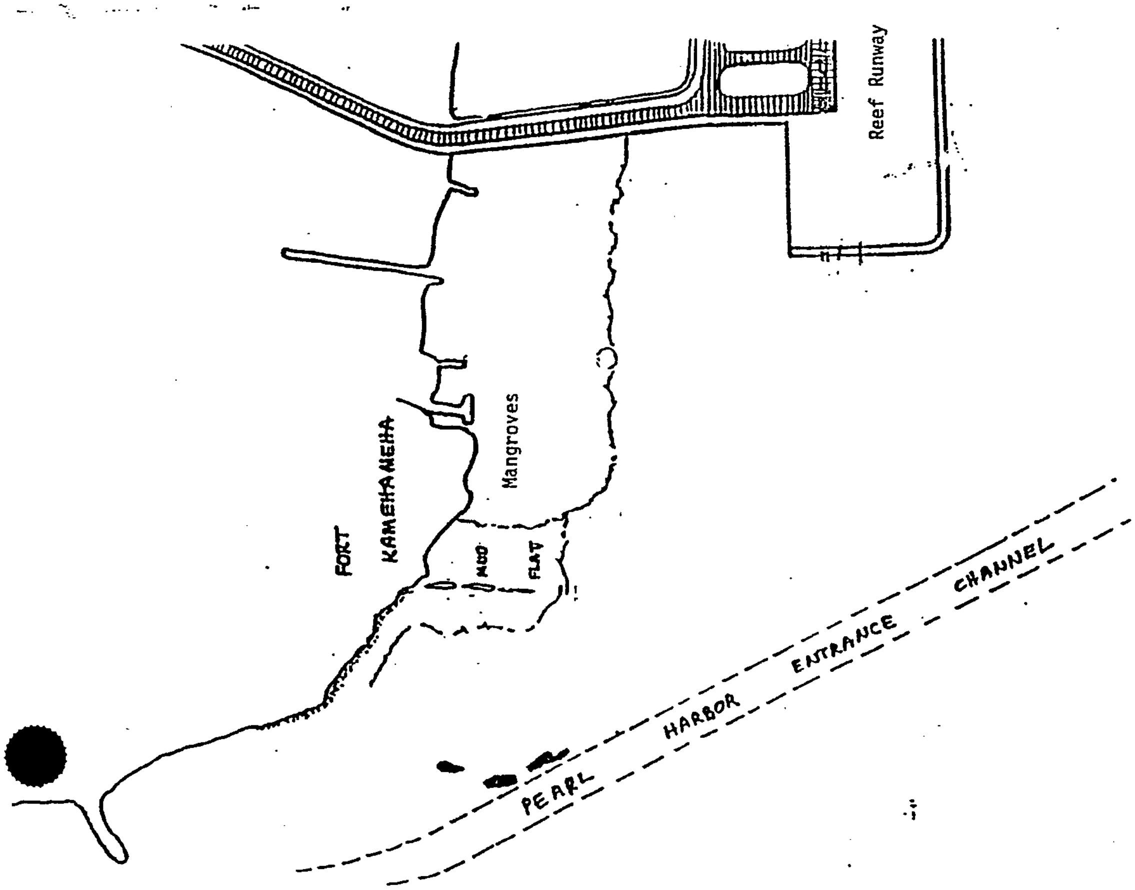


Fig. 1. Location of bird survey. Dark structures east of Pearl Harbor Entrance Channel are sand islets.

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Appendix VI

Assessment of Water Qualilty and Marine Community Structure: Fort Kamehameha Ocean Outfall Extension Oceanographic Study

ASSESSMENT OF WATER QUALITY AND MARINE COMMUNITY STRUCTURE

FORT KAMEHAMEHA OCEAN OUTFALL EXTENSION OCEANOGRAPHIC STUDY

Prepared for:

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I. EXECUTIVE SUMMARY

Planning is underway to extend the outfall for the Fort Kamehameha Wastewater Treatment Plant from the present location along the Pearl Harbor entrance channel to an offshore depth of approximately 37 meters. Evaluation of nearshore water chemistry and marine biotic community structure in the vicinity of the proposed extension of the Fort Kamehameha outfall was conducted from February 1995 to February 1996. In order to determine ambient conditions of water chemistry in the area that is likely to be influenced by effluent discharge from the extended outfall, samples were collected at three depths (surface, mid-depth, and bottom) at ten stations aligned in an east-west orientation offshore of the Pearl Harbor entrance channel. Weather conditions during sampling ranged from tradewind, Kona winds, and no wind, and following periods of rainfall and extended dry weather. Analysis of 13 water chemistry constituents included all parameters specified in DOH water quality standards.

Results of water chemistry analyses revealed a region of reduced salinity and elevated dissolved nutrients (Si, NO_3^- and PO_4^{3-}), turbidity and chlorophyll within the Pearl Harbor channel south of the present Fort Kamehemaha discharge. This result is consistent with past surveys which documented that the seaward flow of water carrying both sewage effluent and estuarine water from the inner lochs of Pearl Harbor results in a surface plume of lower salinity, higher nutrient water in the entrance channel. Results of the present survey, which was not restricted to the present ZOM for the existing outfall, revealed that the predominant flow of water exiting Pearl Harbor is to the west. The westward flow is most apparent during tradewind and light and variable winds, and least apparent during Kona winds. The flow of water exiting the Harbor is confined primarily to the surface layer, owing to density gradients associated with reduced salinity. Thus, a surface layer with elevated dissolved nutrients, turbidity and chlorophyll can be tracked in the open ocean to the west of the Pearl Harbor channel. No such layer was detected to the east of the channel. The depressed salinity and elevated nutrients and turbidity was greatest following a period of moderate rainfall in November 1995. Westward flow is not evident at mid-depths or near the

bottom, and there is little difference between values of water chemistry constituents at these depths between stations located to the east or west of the channel. In addition, there is little indication of difference in water chemistry at stations located at water depths of 37 m or 73 m.

Continuous vertical profiles of salinity reveal steep gradients of increasing salinity in the upper 5 m of many stations. These gradients are most pronounced at stations closest to the present Fort Kamehameha WWTP discharge, and reflect low salinity water flowing out of the Harbor in a surface layer. At the offshore ocean stations, vertical stratification of salinity appears to be a function of wind direction. During tradewind conditions, the surface plume can be detected at stations downwind (to the west) of the Harbor channel. During Kona winds, stratification is apparent at stations to the east of the channel, and is virtually absent to the west. Below the surface layer, there is little indication of sub-surface anomalies in salinity.

Continuous profiles of temperature indicated that overall water temperature varied seasonally, with warmest temperatures in November and coolest in May. Most profiles showed gradual cooling with depth in the water column. Several offshore stations exhibited steep temperature gradients at depths of 50-70 m, indicating that the profile had penetrated the thermocline.

When considering geometric means of sample concentrations from each sampling depth, the only geometric means that exceeded the State of Hawaii Department of Health water quality standards were NO_3^- and Chl. a at the surface of the station just beyond the mouth of Pearl Harbor. No geometric means of sample values pooled from all depths at each station exceeded any of the State standards.

A potential route of the extended outfall crosses a flat platform reef on the along the eastern side of the Pearl Harbor entrance channel. Predominant biota on the inner, nearshore sand-covered area of the reef are benthic algae and sea cucumbers. The outer region of the reef platform contains massive colonies of reef corals, predominantly of the species *Porites compressa*. These colonies appear as elongated ridges and "micro-atolls" that grow from the sandy bottom almost to the ocean surface. Cover of living coral increases with distance seaward until the channel cut or outer edge of the reef platform is reached. The sand flat terminates along the channel in a near vertical surface that is inhabited by a variety of sessile invertebrates, particularly sponges. A unique observation of the existing diffuser is that numerous small green sea turtles use the space between the outfall pipe and the channel floor as a refuge habitat.

The offshore habitat of the potential routes of the extended outfall consists predominantly of a sandy plain, with substantial amounts of coral rubble fragments. Interspersed over the sand plain are numerous "patch reefs", consisting of areas of denser accumulations of rubble and communities of living reef corals. Growth forms of the corals are generally lobate, restricting vertical relief to less than 1 m off the sand surface. Owing to the increased substratum complexity created by the coral and rubble, reef fish abundance (particularly of small individuals or juveniles) is substantially elevated compared to the surrounding sand flats. It was estimated that the patch reefs may comprise on the order of 5-10% of bottom cover of the surveyed outfall routes.

II. INTRODUCTION

A. PROJECT DESCRIPTION

The Waste Water Treatment Plant (WWTP) at Fort Kamehameha was constructed in 1968 and treats domestic and industrial wastewater from the Pearl Harbor Naval Base, Hickam Air Force Base, and Hickam Village. The treatment plant is operated by the U.S. Navy. The effluent is presently discharged through a reinforced concrete pipe 549 meters (m) long, and 76 centimeters (cm) in diameter that runs along the east side of the Pearl Harbor entrance channel. The pipe terminates in a multi-port diffuser at the eastern edge of the entrance channel at a depth of 13.7 m. The receiving waters at the existing discharge site are regulated as a Class 2 inland estuary under current State of Hawaii Department of Health regulations.

The WWTP at Fort Kamehameha is presently being expanded to meet higher projected flows. The present flow is 7.5 million gallons per day (MGD), while the projected average, maximum and peak flows are 13, 20 and 30 MGD, respectively. State regulations are very restrictive and stipulate that "no new industrial or sewage discharges will be permitted within estuaries". Thus, extending the outfall to discharge effluent into Class A "wet" open coastal waters will allow the projected increased flows to be discharged in compliance with existing regulatory requirements.

Initially, the Navy considered constructing a 1,300 m long, 92 cm diameter outfall, terminating in 19 m water, approximately midway out of the Pearl Harbor entrance Channel. However, as the 37 m depth is only about 200 m beyond the 19 m contour, and as preliminary modeling indicated a much smaller Zone of Mixing (ZOM) at the 37 m depth, the deeper contour was selected as the projected discharge depth. As a result, all oceanographic studies target the 37 m depth as the point of discharge.

As part of the environmental documentation required to support the proposed project, studies were conducted to assess the marine ecosystems in the vicinity of the proposed outfall and diffuser locations. One component of these studies includes evaluation of water chemistry in the area of the probable Zone of Mixing (ZOM) of the extended outfall, and qualitative descriptions of the marine biotic community structure in the area of the probable outfall routes. These surveys provide the baseline of background conditions, as well as a basis for evaluation of possible environmental consequences of the proposed project. Presented below are the methods, results and discussion of the assessment of the marine environment in the vicinity of area of the Fort Kamehameha Outfall extension.

B. PREVIOUS STUDIES OF THE FORT KAMEHAMEHA WWTP

Prior to the present investigation, several studies have evaluated the effects of effluent discharge of the Fort Kamehameha WWTP on receiving waters. In 1973-75, water chemistry data were collected for the purpose of defining an appropriate zone of mixing in Pearl Harbor. Results of these studies are summarized in a document entitled "Determination of a Zone of Mixing for the Fort Kamehameha Sewage Treatment Plant Discharge" prepared by Surface et al., Environmental Branch, Pacific Division, Naval Facilities Engineering Command (1975). Results of this work showed no significant effects of the discharge on the quality of receiving waters except for total phosphorus.

As part of the Environmental Impact Statement prepared in anticipation of expanding and upgrading the Fort Kamehameha WWTP to accommodate projected peak flows, surveys were conducted by Marine Research Consultants in March and June 1992. These studies were aimed at addressing the requirement that the increased discharge must remain within the National Pollution Discharge Elimination System (NPDES) and State of Hawaii permit limitations. Sampling was limited to within the ZOM (a trapezoid defined by a 7,500 foot long base at the mouth of Pearl Harbor, a 1,000 foot top perpendicular to the axis of the Pearl Harbor Channel, and 8,000 foot sides defined by the west and east shorelines of the channel). Results of these surveys revealed plumes containing low salinity and elevated nutrients distributed through the ZOM. In addition, survey results revealed that some water quality elevated water quality constituents that exceeded State Water standards were the result of discharge of estuarine water from inner Pearl Harbor, and were not a result of sewage effluent discharge.

Results of the 1992 studies indicated that effects of the sewage effluent on receiving waters differed substantially under different weather and sea conditions. To address this variation, quarterly sampling was conducted for a year (Marine Research Consultants 1992, 1993) at 12 stations within and beyond the Zone of Mixing. Results of the year long program revealed that the geometric means of all samples collected at the boundaries of the ZOM were within State of Hawaii water quality standards.

III. RESULTS and DISCUSSION

A. WATER CHEMISTRY

1. Methods

An important consideration of extending the Fort Kamehameha Outfall is the effect that discharge of effluent will have on receiving waters. In order to address this effect it is necessary to have a valid data base representing existing conditions of water chemistry in the area of the proposed extended outfall. With this goal in mind, a water chemistry sampling program was carried out over a 12-month period from February 1995 to February 1996. Sampling was conducted approximately bi-monthly (one sampling every two months). In addition, a Th sampling was conducted following a period of heavy rainfall.

Water samples were collected at the surface, at mid-depth and near that bottom at 10 stations in the vicinity of the existing and proposed Fort Kamehameha Outfalls. Figure 1 is a map of the area of the area off the Pearl Harbor entrance channel showing the locations of the 10 water sampling stations. Station 1 was located just seaward of the existing Fort Kamehameha Outfall. Stations 3, 5, 7, and 9 were located at a water depth of approximately 37 meters (m), while Stations 4, 6, 8, and 10 were located at water depth of approximately 73 m. These two depths are considered as potential depths of the proposed outfall extension.

Water sampling was conducted on Feb. 27, May 1, June 29, Sept. 14, and Nov. 7, 1995, and Jan. 6 and Feb. 7, 1996. Both the Nov. 7, 1995 and Jan. 6, 1996 were conducted following periods of moderate rainfall and runoff. Sea conditions during the samplings

consisted of a range of conditions from tradewinds (5/1/95, 6/29/95, 11/7/95) to Kona winds (1/6/96, 2/7/96) to light and variable winds (2/27/95, 9/14/95).

Water samples were collected from a boat using a 1.8 liter Niskin-type oceanographic sampling bottle. The bottle was lowered to the desired sampling depth with endcaps cocked in an open position so that water flowed freely through the bottle. At the desired depth a weighted messenger released from the surface tripped the endcaps closed, isolating a volume of water from the desired sampling depth. At all sampling stations, three water samples were collected; a surface sample from within 10 centimeters (cm) of the air-sea interface, a mid-depth sample, and a deep sample within 50 cm of the ocean floor.

Water quality constituents that were evaluated include the 9 specific criteria designated for inland waters in Chapter 11-54, Section 05 (Pearl Harbor waters) of the Water Quality Standards, Department of Health, State of Hawaii. These criteria include: total dissolved nitrogen (TDN), nitrate + nitrite nitrogen ($NO_3^- + NO_2^-$), ammonium (NH_4^+), total dissolved phosphorus (TDP), chlorophyll a (Chl a), turbidity, salinity, pH and temperature. In addition, orthophosphate phosphorus (PO_4^{-3}), silica (Si), dissolved organic nitrogen (DON) and dissolved organic phosphorus (DOP) are also reported because these constituents can be indicators of biological activity and the degree of inputs from terrestrial sources.

Subsamples for nutrient analyses were immediately passed through sub-micron filters (GF-F) into 125-milliliter (ml) acid-washed, triple rinsed, polyethylene bottles and stored on ice until returned to the laboratory. Analyses for NH_4^+, PO_4^{3-}, NO_3^-, and Si were performed using a Technicon autoanalyzer according to standard methods for seawater analysis (Strickland and Parsons 1968, Grasshoff 1983). TDN and TDP were analyzed in a similar fashion following oxidative digestion. Dissolved organic nitrogen (DON) and dissolved organic phosphorus (DOP) were calculated as the difference between TDN and dissolved inorganic N, and TDP and dissolved inorganic P, respectively. The level of detection for the dissolved nutrients is 0.2 µM for TDN and Si, 0.02 µM for TDP, and 0.01 µM for PO_4^{3-}, NO_3^- and NH_4^+.

Water for other analyses was subsampled from 1-liter polyethylene bottles and kept

chilled until analysis. Turbidity was determined on 60-ml subsamples fixed with $HgCl_2$ to terminate biological activity. Fixed samples were kept refrigerated until turbidity was measured on a Monitek Model 21 90-degree nephelometer, and reported in nephelometric turbidity units (ntu) (level of detection 0.01 ntu). Chl a was measured by filtering 300 ml of water through glass fiber filters; pigments on filters were extracted in 90% acetone in the dark at -5° C for 12-24 hours, and the fluorescence before and after acidification of the extract was measured with a Turner Designs fluorometer (level of detection 0.01 µg/L). Salinity was determined using an AGE Model 2100 laboratory salinometer with a precision of 0.0003 ‰. pH was determined using a field meter with a combination electrode with precision of 0.01 pH units.

Nutrient, turbidity, Chl a and salinity analyses were conducted by Marine Analytical Specialists (Laboratory Certification NO: HI-0009) of Honolulu, HI.

Continuous profiles of salinity and temperature were acquired using a Ocean Sensors Model 100 CTD,

2. Results of Water Chemistry Analyses

Tables 1-7 show results of all water chemistry analyses for all samples collected during each of the seven sampling events. Also shown in Tables 1-7 are the water depths at each of the sampling stations. Table 8 shows the geometric means for the 7 samples collected at each sampling depth at each station, while Table 9 shows the geometric means for the composite of all 21 samples at all three depths at each sampling station. Figures 2-9 are scatter plots that show concentrations of eight chemical constituents at each sampling station during each of the seven sampling events. Separate plots are shown for each sampling depth (surface, mid-depth and bottom). With the pattern of sampling stations (see Figure 1) it is not possible to graphically represent the sampling scheme in an exact geographical setting. Thus, while the orientation of sampling sites in Figures 2-9 runs approximately from east to west, it should be noted that some of the stations (notably Stations 1 and 2) do not actually occur in this spatial orientation.

Several overall points can be made regarding the horizontal and vertical distribution of water chemistry constituents from the data sets as represented in Figures 2-9. First, salinity is often lower, and dissolved nutrients higher at Stations 1 and 2, located within the Pearl Harbor entrance channel, than at Stations 3-10, located in an open ocean setting beyond the entrance channel. This trend is especially apparent at Station 1 located very close to the existing discharge of the Fort Kamehameha WWTP. At Station 1, surface and mid-depth concentrations of NO_3^- and PO_4^{3-} exhibit markedly higher concentrations, while salinity is substantially lower than in bottom water. These elevated concentrations of the inorganic nutrients present in sewage effluent, along with reduced salinities, indicate that surface and mid-depth samples were collected in the surfacing plume of the present Fort Kamehameha diffuser. In addition, the stations within the channel may reflect characteristics of estuarine water flowing seaward from within the inner lochs of Pearl Harbor. As a result, it is obvious that conditions of water chemistry within the Harbor channel are substantially different than those at sampling stations beyond the channel (Stations 3-10).

Another result is that variability of salinity and inorganic nutrient concentrations is greater at offshore stations to the west of the Pearl Harbor channel (Stations 7-10) than at stations located directly off the entrance channel, or to the east of the channel (Stations 3-6). This pattern is especially apparent in the surface scatter plots of salinity (Figure 2), Si (Figure 3), and NO_3^- (Figure 4). As described above, these constituents are good tracers of freshwater and sewage effluent. Thus, the pattern of distribution along the east-west axis indicates that the dominant direction of longshore flow of water exiting the Harbor mouth is to the west. This pattern is most apparent during samplings conducted on November 14 following a period of rainfall. In addition, it also appears that westward flow occurs during tradewinds or light and variable winds, and is least apparent during Kona wind conditions. Inspection of Table 8, which shows geometric means at each sampling location also reveal the increased influence of freshwater constituents in surface waters to the west of the channel entrance. Geometric means of salinity in surface samples at stations to the west of the channel are all below 34.5‰, while to the east surface salinities are all above 34.6‰. Similarly, geometric mean concentrations of Si in surface samples to the west of the channel are all above 75 µg/L, while geometric means of surface water at Stations 4-6 are below 63 µg/L.

The pattern of apparent longshore westward flow of water exiting the Pearl Harbor channel is also apparent in the scatter plots of turbidity (Figure 9). As with inorganic dissolved nutrients, values of turbidity peak at Stations 1 and 2, likely as a result of the high particulate loads resulting from effluent discharge and estuarine processes. Values at stations to the west of the channel reveal substantially more scatter and higher concentrations than stations to the east of the channel. All values of turbidity at Stations to the east of the Harbor channel are below 0.2 n.t.u. reflecting open ocean conditions throughout the sampling period.

As is evident in Figures 2-9, there is distinct indication of westward flow of water based on the patterns of constituents are found in higher concentration in Pearl Harbor water (e.g. salinity, NO_3^-, Si, PO_4^{3-}). However, constituents that do not occur in elevated concentrations at the inner Pearl Harbor stations (Stations 1 and 2) do not exhibit the same trends. Scatter plots of TDN (Figure 5), and TDP (Figure 8), as well as temperature, pH (Tables 1-7) show little indication of change moving east to west. Scatter plots of NH_4^+, the reduced form of nitrogen that is often a component of sewage effluent does not exhibit the same pattern of elevated concentrations in surface and mid-depth samples at Station 1 as NO_3^-, Si, and PO_4^{3-}. Also, there is no clear indication of elevated concentrations of NH_4^+ at offshore stations to the west of the Harbor channel (Stations 7-10) compared to stations to the east (Stations 3-6). These patterns suggest that concentrations of NH_4^+ at the open ocean sampling stations are not substantially influenced by flow of water from Pearl Harbor, but rather reflect nearshore oceanic conditions. Previous studies of water chemistry within the ZOM of the Fort Kamehameha WWTP also report little influence on concentrations of NH_4^+ as a result of the sewage effluent discharge (Marine Research Consultants 1992, 1993).

While there is substantial indication of influence to offshore surface waters by discharge from Pearl Harbor, there appears to be little effect to at mid-depths and bottom depths. Inspection of Figures 2-9 indicates that at the oceanic stations beyond the Harbor entrance (Stations 3-10) there is little variation in concentrations between mid-depth and bottom samples. In addition, there is little variation in both mid-depth and bottom samples in the oceanic stations in an east-west orientation. These results indicate that water flowing from Pearl Harbor is restricted to a surface layer owing to decreased salinity that does not readily mix through the water column.

Figures 10-36 show vertical profiles of salinity and temperature at each of the sampling stations acquired during each of the seven samplings. Profiles are grouped on each page according to depth; the six inshore shallow stations are shown on one figure, while the four offshore deep stations are shown on the following figure.

The most apparent feature of the salinity profiles is the steep gradients in the upper 5 m of many of the plots. The surface gradients are most pronounced and most consistent at Station 1, and reflect the surface layer of low salinity water flowing out of the Pearl Harbor channel. As discussed above, the low salinity layer is likely a result of discharge of both effluent from the Fort Kamehameha WWTP and estuarine water from inner Pearl Harbor.

The degree of vertical stratification of salinity in the upper 5 m of the water column at the other sampling stations can be seen to vary from survey to survey. In large part the variation is a function of wind direction. Most notable is the reduced stratification at stations to the east of the Pearl Harbor channel (Stations 4-6) and pronounced stratification at the Stations to the west of the channel (Stations 7-10) during tradewind conditions (for example, see Figures 26 and collected on November 7, 1995). Alternatively, during Kona wind conditions, stratification was most pronounced at the stations to the east of the channel, and substantially reduced to the west of the channel (see Figures 34 and 35 collected on February 7, 1996).

Inspection of all of vertical profiles of salinity reveal that there is little indication of sub-surface anomalies. Below the upper 5 m of the water column, there is little variation in salinity. An exception to this pattern, however, is evident in the profiles collected on July 14, 1995 (profiles were collected on this date owing to a malfunction of the CTD on June 29, 1995). On July 14, a subsurface layer of water of elevated salinity (up to 34.9‰) was evident at a depth of 60 m.

Profiles of temperature exhibited various patterns. Over the course of the year of sampling, surface water temperature was warmest in November and coolest in May. Most of the inshore stations showed either little variation in temperature through the

water column or gradual cooling with depth. Profiles at the deep offshore stations showed generally exhibited gradual cooling with depth. Several stations, however, exhibited steep gradients in temperature at depths of 50-70 m, indicating that the profile penetrated the thermocline. The strongest gradients in temperature at depth occurred at Station 6 on July 14, 1995 (Figure 21), Station 4 on September 14, 1995 (Figure 25) and November 7, 1995 (Figure 29). There was no apparent indication of temperature anomalies on the sampling days following rainfall.

3. Compliance with DOH Criteria

State of Hawaii Department of Health (DOH) water quality standards specify the following specific criteria for geometric means not to exceed the given value for open coastal waters under "wet" conditions:

Total Nitrogen	150 µg/L
Total Phosphorus	20 µg/L
Ammonia Nitrogen	3.50 µg/L
Nitrate Nitrogen	5.00 µg/L
Chlorophyll a	0.30 µg/L
Turbidity	0.50 n.t.u.

When considering geometric means of samples collected at each sampling depth, it can be seen in Table 8 that at the open ocean stations beyond the mouth of Pearl Harbor (Stations 2-10) the only geometric means that exceed these specific limits are at Station 2. Surface samples at Station 2 exceeded the geometric mean limits of NO_3^- (7.40 µg/L) and Chl a (0.39 µg/L). None of the geometric means of samples from stations 3-10 exceeded any of the geometric mean limits. When considering the geometric means of pooled samples from all depths at each station (Table 9), none of the sample values exceeded specified limits.

B. BIOTIC COMMUNITY STRUCTURE

1. Methods

Qualitative assessments of the marine biotic communities along the prospective outfall routes were conducted by field personnel using several methods. Survey of the nearshore reef bench on the eastern side of the Pearl Harbor entrance channel fronting Hickam Beach was conducted by walking across the reef flat from the shoreline seaward to the channel cut. The path of survey zig-zagged across the reef flat covering all areas of possible outfall routes from channel cut eastward. At selected areas during the walking surveys, snorkeling surveys were made to identify dominant biota.

Surveys of the potential outfall routes in deeper water beyond the reef flat were conducted by divers towing behind a boat using a steerable tow-sled. The sled could be steered in both horizontal and vertical planes so that investigators could steer the sled to as close to the bottom as desired. Tow surveys initiated at the outer points of the outfall route at a depth of about 37 m and proceeded shoreward along the proposed routes to the edge of the Pearl Harbor channel cut fronting the reef flat. Two tow surveys were conducted; one along the eastern edge of the channel, and one along the western edge of the channel. While the western side of the channel is not considered a potential outfall route, a tow survey was conducted to determine comparative differences between the two sides of the entrance channel. Tow surveys provide the advantage of covering a large distance underwater in a minimum of time.

2. Results

a. Reef Flat

The nearshore area on the eastern side of the Pearl Harbor channel fronting the Fort Kamehameha WWTP consists of a broad, shallow platform reef. Depth of the platform does not exceed 2 m at the seaward limits. In this context, the term reef refers to a limestone platform that was likely accreted at a much earlier stands of sea level. It is not considered a modern reef that is actively accreting at present.

The predominant cover of the nearshore reef surface is coarse grey calcareous muddy sand. The sandy surface is marked by numerous burrow holes, likely from either burrowing alpheid shrimp and/or worms. Much of the sand flat is covered by dense mats of the brown algae *Acanthophora specifera*. Other marine algae that were observed on the inner reef flat were *Padina spp., Caulerpa spp., Enteromorpha sp.* The dominant fauna on the inner reef were the sea cucumber *Ophiodesoma spectabilis,* which are gelatinous, translucent, orange-colored organisms up to 0.5 m in length. These organisms are common in mud bottom areas with high organic particulate content.

Approximately midway on the reef platform are a several islets covered with mangroves. At the seaward edges of the islets, colonies of the branching reef coral *Porites compressa* begin to occur on the sandy bottom. Aside from *Porites compressa,* the only coral observed on the reef flat was *Pocillopora damicornis.* Moving seaward of the mangrove islets, abundance of living corals increased with distance from shore. Approximately 100 m from the islets, elongated ridges of corals oriented perpendicular to the channel axis extended across the sand flats. Also scattered over the outer sand flats were "micro-atolls" of *Porites compressa.* These structures consist of circular colonies up to 5 m in diameter of living coral that extend almost to the ocean surface. The centers of these structures do not contain living coral tissue as a result of exposure to the atmosphere. Thus, growth is restricted to the lateral direction resulting in the large size of the colonies. From above, these structures appear to be doughnut-shaped with hollowed out centers. Coral cover at the seaward regions of the reef flat was on the order of 25% bottom cover.

Reef fish were not abundant on the reef flat during the qualitative survey. This observation may have partly a result of the method of the survey which was not designed to investigate sheltered areas where fish may find refuge. It has also been noted that the reef flat is subjected to high levels of fishing pressure. Throughout the year of sampling, fisherman were consistently observed on the flats.

The reef flat terminates in an abrupt vertical wall of the dredged channel on the western edge and a less abrupt, but still distinct sharp gradient off the southern region fronting the open ocean. Channel walls are inhabited by a variety of sessile

invertebrates, primarily sponges, alcyonarians, polychaete and sipunculid worms and bivalve mollusks. Inspection of the existing Fort Kamehameha outfall along the eastern channel wall adjacent to the reef flat revealed relatively large aggregations of green sea turtles (*Chelonia mydas*). It appeared that these turtles use the space between the outfall pipe and the channel floor as a refuge area. Approach by divers caused the turtles to move from the shelter space adjacent to the outfall and disperse. It is noteworthy, however, that turtles appeared to aggregate in the area in response to the habitat provided by the outfall structure in the region where effluent concentrations in the water were greatest.

b. Offshore Outfall Routes

The offshore outfall routes were qualitatively surveyed from a depth of 37 m to the channel wall off the reef flat, a distance of approximately 2 kilometers. While this is a relatively large distance, the physical and biotic diversity is rather low; most of the area is homogeneous with little variation. Both routes on the east and west sides of the entrance channel were qualitatively similar, with no major differences.

At the most seaward areas of the survey, bottom composition consists almost entirely of gray sand. In many areas the sand exhibited ripple marks indicating resuspension and movement by currents. In other areas the sand surface was flat and covered with a greenish film, most likely consisting of benthic diatoms. Existence of benthic films suggests little movement of sediment by wave and current forces. Moving shoreward, the sand bottom grades gradually into a sand/rubble mixture. Rubble fragments appear to be primarily the remains of reef corals that had probably been broken from the reef by storm or hurricane waves.

Interspersed across the bottom within the sand/rubble habitat are features that might be termed "patch reefs". These structures are not true "reefs" in that there is not an upward accreting solid limestone platform. Rather, these areas consist of denser aggregations of limestone rubble with a component of living corals. The dominant corals on these patch reefs are *Porites compressa, Porites lobata, Pocillopora meandrina* and *Montipora verrucosa.* Growth forms of most of the corals on these patch reefs consisted of flat encrustations, and massive lobed colonies. Thus, while the

patch reefs had a substantially higher vertical relief than the sand plain, there is not marked vertical relief of greater than approximately 25-50 cm. Living coral cover on the patch reefs is estimated on the order of 20%. Integrated over the entire sand/rubble plain, the patch reefs may comprise approximately 5-10% of bottom cover, while living coral cover is estimated at less than 2-5% of bottom cover.

These reefs provide habitat for a variety of reef fish, particularly butterflyfish (Chaetodontidae), goatfish (Mullidae), wrasses (Labridae), damselfish (Pomacentridae), surgeon fish (Acanthuridae) and triggerfish (Balistidae). Most of the fish observed in the tow survey were juveniles or small adults. Other dominant biota observed on the sea urchins *Heterocentrotus mammilatus, Echinometra mathei, Echinothrix diadema,* and *Tripneustes gratilla.* Owing to the nature of the rapid qualitative survey, it was not possible to assess infauna or cryptic fauna on the patch reefs.

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TABLE 1. Water chemistry measurements (in µg/L) from waters in the vicinity of Fort Kamehameha sewage outfall extension collected on February 27, 1995. Abbreviations as follows: S=surface; M=mid; D=deep; BDL=below detection limit. For sampling locations, see Figure 1.

STATION	DEPTH (m)	SAMPLE NO.		PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	Si (µg/L)	DOP (µg/L)	DON (µg/L)	TDP (µg/L)	TON (µg/L)	TURB (ntu)	SAL (o/oo)	CHL a (µg/L)	TEMP (deg C)	pH
		1	S	3.41	3.22	0.70	990.73	8.98	96.08	12.40	99.96	0.53	33.090	1.25	24.5	8.15
1	11	2	M	4.96	7.28	0.42	232.30	17.65	80.39	22.63	88.06	0.41	34.404	0.82	24.5	8.18
		3	D	3.41	1.96	1.68	110.39	8.05	78.71	11.47	82.32	0.54	34.697	0.45	24.5	8.18
		4	S	4.03	4.90	0.70	180.90	7.12	90.62	11.16	96.18	0.28	34.525	0.36	24.1	8.16
2	6	5	M	4.03	3.64	1.26	100.84	9.60	93.56	13.64	98.42	0.15	34.666	0.21	24.3	8.17
		6	D	3.41	3.78	0.70	98.88	11.15	89.64	14.57	94.06	0.17	34.677	0.19	24.2	8.17
		7	S	3.10	1.96	0.84	118.26	8.98	93.42	12.09	98.18	0.14	34.636	0.32	24.1	8.18
3	36	8	M	2.79	0.42	0.70	83.15	8.98	82.06	11.78	83.16	0.09	34.710	0.26	24.2	8.19
		9	D	2.79	0.70	2.10	77.81	8.98	97.20	11.78	99.98	0.09	34.702	0.25	24.1	8.19
		10	S	3.41	6.58	1.68	162.08	8.67	91.60	12.09	99.82	0.16	34.568	0.35	24.1	8.17
4	73	11	M	2.48	0.28	1.68	77.81	9.29	92.72	11.78	94.64	0.15	34.710	0.31	24.1	8.19
		12	D	2.48	0.42	1.54	75.84	8.67	90.06	11.16	91.98	0.10	34.706	0.27	24.0	8.19
		13	S	2.48	1.96	2.10	101.97	8.67	101.68	11.16	105.70	0.16	34.663	0.30	24.2	8.17
5	18	14	M	2.48	1.68	1.40	86.80	8.36	79.55	10.85	82.60	0.18	34.687	0.30	24.2	8.18
		15	D	2.79	1.82	2.38	86.24	7.74	82.64	10.54	86.80	0.14	34.703	0.31	24.1	8.18
		16	S	2.79	1.82	1.26	109.55	8.05	90.76	10.85	93.80	0.16	34.658	0.38	24.2	8.18
6	66	17	M	2.48	0.14	1.82	71.35	8.05	87.96	10.54	89.88	0.09	34.700	0.28	24.2	8.19
		18	D	2.17	BDL	1.54	67.42	7.74	67.37	9.92	68.88	0.09	34.706	0.22	24.3	8.19
		19	S	3.10	5.18	1.40	605.06	7.43	98.60	10.54	105.14	0.34	33.799	1.00	24.1	8.15
7	11	20	M	2.79	2.24	1.82	165.17	7.43	84.60	10.23	88.62	0.17	34.548	0.41	24.4	8.17
		21	D	2.48	1.54	2.66	86.52	8.05	85.72	10.54	89.88	0.12	34.712	0.19	24.1	8.17
		22	S	2.79	4.76	2.38	421.07	9.29	106.87	12.09	113.96	0.30	34.077	0.55	23.8	8.14
8	64	23	M	2.48	0.70	2.10	115.45	8.36	88.38	10.85	91.14	0.13	34.650	0.26	24.0	8.18
		24	D	2.48	0.70	2.94	86.24	8.05	78.99	10.54	82.60	0.13	34.703	0.23	24.4	8.18
		25	S	3.72	4.76	3.78	360.11	8.05	92.86	11.78	101.36	0.25	34.183	0.37	24.1	8.13
9	12	26	M	2.79	0.84	2.38	89.05	8.36	93.28	11.16	98.46	0.13	34.689	0.23	24.0	8.18
		27	D	2.79	1.12	2.94	89.89	8.05	93.00	10.85	97.02	0.12	34.698	0.22	23.9	8.18
		28	S	1.86	0.28	3.08	64.89	8.36	89.82	10.23	93.24	0.11	34.753	0.09	24.0	8.19
10	73	29	M	1.86	0.28	2.52	66.57	8.05	74.65	9.92	77.42	0.09	34.741	0.16	23.9	8.19
		30	D	1.86	0.14	2.66	67.42	7.43	72.69	9.30	75.46	0.11	34.748	0.15	24.3	8.19

TABLE 2. Water chemistry measurements (in μg/L) from waters in the vicinity of Fort Kamehameha sewage outfall extension collected on May 1, 1995. Abbreviations as follows: S=surface; M=mid; D=deep; BDL=below detection limit. For sampling locations, see Figure 1.

STATION	DEPTH (m)	SAMPLE NO.	PO4 (μg/L)	NO3 (μg/L)	NH4 (μg/L)	Si (μg/L)	DOP (μg/L)	DON (μg/L)	TDP (μg/L)	TDN (μg/L)	TURB (ntu)	SAL (o/oo)	CHL a (μg/L)	TEMP (deg C)	pH
		1 S	3.10	6.16	5.04	310.11	9.60	84.60	12.71	95.76	0.28	34.250	0.52	23.4	8.08
1	11	2 M	2.17	3.50	3.78	102.25	9.29	86.94	11.47	96.18	0.16	34.664	0.46	23.5	8.11
		3 D	2.48	4.34	2.66	168.62	8.98	94.12	11.47	101.08	0.18	34.525	0.63	23.5	8.10
		4 S	1.24	2.52	2.66	63.76	9.91	97.90	11.16	103.04	0.17	34.718	0.31	23.3	8.11
2	6	5 M	1.55	3.50	2.10	64.33	9.91	94.68	11.47	100.24	0.14	34.701	0.28	23.3	8.10
		6 D	1.55	4.06	4.06	65.73	9.91	89.22	11.47	97.30	0.14	34.710	0.23	23.3	8.10
		7 S	0.93	1.40	2.52	51.69	9.60	90.34	10.54	94.22	0.10	34.738	0.28	23.5	8.12
3	36	8 M	0.93	1.12	2.38	52.25	9.60	93.42	10.54	96.88	0.09	34.727	0.31	23.5	8.12
		9 D	0.62	1.26	3.36	51.69	9.91	95.10	10.54	99.68	0.11	34.728	0.36	23.5	8.12
		10 S	1.24	2.24	1.68	51.12	10.22	94.68	11.47	98.56	0.15	34.728	0.25	23.6	8.12
4	73	11 M	0.62	1.68	1.96	46.91	9.91	89.22	10.54	92.82	0.11	34.732	0.30	23.5	8.13
		12 D	0.93	1.54	1.96	43.26	9.60	88.24	10.54	91.70	0.11	34.766	0.25	23.3	8.12
		13 S	0.93	2.66	2.66	64.89	9.29	96.92	10.23	102.20	0.13	34.735	0.27	23.6	8.12
5	18	14 M	0.93	2.94	3.08	58.71	9.60	95.52	10.54	101.50	0.17	34.745	0.34	23.4	8.12
		15 D	2.17	8.82	4.48	58.43	9.60	93.14	11.78	106.40	0.12	34.735	0.24	23.3	8.10
		16 S	0.62	3.36	1.96	60.11	9.60	94.68	10.23	99.96	0.14	34.751	0.23	23.6	8.12
6	66	17 M	0.62	2.80	2.66	55.62	9.60	92.86	10.23	98.28	0.15	34.732	0.27	23.6	8.12
		18 D	0.31	2.10	0.84	44.10	9.60	93.56	9.92	98.46	0.16	34.768	0.31	23.4	8.12
		19 S	1.86	2.94	1.68	68.85	9.60	93.00	11.47	97.58	0.17	34.723	0.31	23.5	8.12
7	11	20 M	1.24	3.08	2.10	55.06	9.60	88.94	10.85	94.08	0.14	34.733	0.35	23.5	8.12
		21 D	1.24	2.52	2.38	54.49	9.29	85.44	10.54	90.30	0.12	34.720	0.33	23.5	8.12
		22 S	0.62	2.10	2.80	43.26	9.60	89.22	10.23	94.08	0.12	34.753	0.16	23.6	8.13
8	64	23 M	1.24	1.68	1.82	51.69	9.60	94.54	10.85	98.00	0.10	34.748	0.22	23.5	8.13
		24 D	0.93	1.82	2.10	36.52	9.91	98.74	10.85	102.62	0.11	34.748	0.22	23.5	8.13
		25 S	1.55	0.70	1.12	50.56	9.29	82.44	10.85	94.22	0.10	34.695	0.24	23.5	8.12
9	12	26 M	1.55	1.26	BDL	50.56	9.60	95.52	11.16	96.74	0.09	34.729	0.24	23.5	8.13
		27 D	1.55	1.68	1.12	54.21	9.60	96.50	11.16	99.26	0.17	34.708	0.28	23.5	8.12
		28 S	1.86	1.96	2.10	55.62	9.91	97.48	11.78	101.50	0.10	34.721	0.22	23.5	8.12
10	73	29 M	1.55	2.24	1.96	45.51	9.91	99.58	11.47	103.74	0.09	34.724	0.20	23.5	8.13
		30 D	1.55	2.66	2.94	59.83	9.91	95.10	11.47	100.66	0.08	34.733	0.16	23.4	8.13

TABLE 3. Water chemistry measurements (in μg/L) from waters in the vicinity of Fort Kamehameha sewage outfall extension collected on June 29, 1995. Temperature data was acquired on July 14, 1995. Abbreviations as follows: S=surface; M=mid; D=deep; BDL=below detection limit. For sampling locations, see Figure 1.

STATION	DEPTH (m)	SAMPLE NO.	PO4 (μg/L)	NO3 (μg/L)	NH4 (μg/L)	Si (μg/L)	DOP (μg/L)	DON (μg/L)	TDP (μg/L)	TDN (μg/L)	TURB (ntu)	SAL (o/oo)	CHL a (μg/L)	TEMP (deg C)	pH
		1 S	7.75	18.48	1.54	641.29	3.41	86.14	11.16	108.12	0.49	33.758	0.67	27.3	8.15
1	11	2 M	3.10	1.40	0.14	133.43	4.03	72.55	7.13	74.06	0.30	34.615	0.75	26.5	8.15
		3 D	3.41	1.54	1.40	77.81	4.03	72.27	7.44	75.18	0.50	34.630	0.87	26.5	8.16
		4 S	3.72	3.64	0.14	50.84	3.10	86.70	6.82	90.44	0.25	34.672	0.37	26.6	8.12
2	6	5 M	3.72	3.64	0.56	52.53	3.41	73.25	7.13	77.42	0.31	34.658	0.33	26.5	8.12
		6 D	3.10	3.64	0.56	46.35	3.41	73.25	6.51	77.42	0.28	34.666	0.27	26.5	8.12
		7 S	2.17	0.84	0.28	67.42	4.34	79.41	6.51	80.50	0.18	34.642	0.23	26.5	8.16
3	36	8 M	2.48	0.56	BDL	72.19	5.88	91.04	8.37	91.56	0.16	34.673	0.27	26.4	8.17
		9 D	2.17	0.56	0.14	40.45	5.88	79.55	8.06	80.22	0.15	34.668	0.29	25.7	8.17
		10 S	1.86	0.28	0.56	49.44	4.96	78.43	6.82	79.24	0.11	34.679	0.17	26.4	8.17
4	73	11 M	1.55	0.28	0.28	33.43	5.27	91.04	6.82	91.56	0.11	34.681	0.07	25.5	8.18
		12 D	1.55	0.14	0.98	30.62	4.03	72.55	5.58	73.64	0.11	34.653	0.08	25.1	8.18
		13 S	1.24	0.28	1.26	36.80	4.65	86.00	5.89	87.50	0.12	34.651	0.10	26.8	8.17
5	18	14 M	0.93	0.14	1.12	53.37	3.41	87.40	4.34	88.62	0.14	34.649	0.07	26.4	8.17
		15 D	2.48	0.42	1.96	42.70	4.96	94.68	7.44	97.02	0.12	34.643	0.08	25.9	8.17
		16 S	1.55	0.14	1.12	28.65	4.34	78.15	5.89	79.38	0.09	34.649	0.06	26.5	8.17
6	66	17 M	2.17	BDL	0.56	28.65	5.88	79.97	8.06	80.50	0.09	34.647	0.06	25.3	8.18
		18 D	1.55	0.14	1.40	30.34	5.27	65.97	6.82	67.48	0.10	34.648	0.16	22.6	8.17
		19 S	2.17	0.42	1.40	48.63	4.96	62.75	7.13	64.54	0.14	34.647	0.27	26.6	8.16
7	11	20 M	2.79	0.42	1.82	50.28	4.65	68.21	7.44	70.42	0.18	34.653	0.30	26.4	8.16
		21 D	2.48	0.84	1.26	35.11	4.96	80.53	7.44	82.60	0.15	34.636	0.20	26.4	8.17
		22 S	1.24	0.14	1.12	33.15	4.03	77.87	5.27	79.10	0.12	34.627	0.25	26.5	8.17
8	64	23 M	1.86	0.14	2.24	31.74	5.88	72.83	7.75	75.18	0.14	34.628	0.20	25.5	8.17
		24 D	1.86	0.14	0.70	41.57	5.88	76.89	7.75	77.70	0.14	34.635	0.21	24.0	8.17
		25 S	1.24	0.70	1.40	39.89	3.72	77.17	4.96	79.24	0.13	34.628	0.18	26.5	8.17
9	12	26 M	0.93	0.14	0.70	42.42	3.72	68.21	4.65	69.02	0.19	34.629	0.19	26.4	8.17
		27 D	1.24	0.28	0.98	41.85	5.27	91.32	6.51	92.54	0.19	34.633	0.26	25.9	8.17
		28 S	1.86	0.42	1.68	41.57	5.27	68.91	7.13	70.98	0.11	34.652	0.21	26.5	8.18
10	73	29 M	1.24	0.42	0.98	37.92	5.27	67.37	6.51	68.74	0.11	34.653	0.14	25.7	8.18
		30 D	2.17	0.42	1.82	53.09	5.27	65.69	7.44	67.90	0.12	34.662	0.19	25.5	8.18

TABLE 5. Water chemistry measurements (in µg/L) from waters in the vicinity of Fort Kamehameha sewage outfall extension collected on November 7, 1995. Abbreviations as follows: S=surface; M=mid; D=deep. For sampling locations, see Figure 1.

STATION	DEPTH (m)	SAMPLE NO.		PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	Si (µg/L)	DOP (µg/L)	DON (µg/L)	TDP (µg/L)	TDN (µg/L)	TURB (ntu)	SAL (o/oo)	CHL a (µg/L)	TEMP (deg C)	pH
		1	S	0.93	4.62	0.84	1320.23	10.22	118.49	11.16	123.90	0.67	30.671	0.93	26.8	8.13
1	11	2	M	4.03	7.28	1.96	157.58	9.29	84.32	13.33	93.52	0.35	34.461	0.46	26.9	8.11
		3	D	3.10	3.22	1.82	82.87	9.29	84.32	12.40	89.32	0.36	34.613	0.30	26.9	8.11
		4	S	4.03	11.62	1.54	265.17	8.98	89.64	13.02	102.76	0.33	33.975	0.28	26.8	8.08
2	6	5	M	2.79	2.66	2.80	52.53	9.29	77.73	12.09	83.16	0.23	34.652	0.20	26.8	8.11
		6	D	2.79	2.38	3.36	53.93	9.29	79.69	12.09	85.40	0.40	34.654	0.21	26.8	8.11
		7	S	2.79	2.38	3.50	48.88	8.98	90.20	11.78	96.04	0.15	34.643	0.12	26.7	8.12
3	36	8	M	2.17	0.56	1.96	34.55	9.91	85.02	12.09	87.50	0.11	34.703	0.11	26.5	8.13
		9	D	2.48	0.70	2.94	41.85	9.91	82.08	12.40	85.68	0.08	34.727	0.16	26.4	8.12
		10	S	3.41	1.54	6.02	64.33	9.91	142.86	13.33	150.36	0.13	34.592	0.15	26.7	8.12
4	73	11	M	2.48	0.56	2.52	34.27	9.60	79.13	12.09	82.18	0.11	34.751	0.10	26.0	8.13
		12	D	2.79	3.78	2.52	40.17	10.22	87.54	13.02	93.80	0.16	34.883	0.14	23.2	8.09
		13	S	2.79	1.54	2.52	40.17	8.98	78.99	11.78	83.02	0.10	34.693	0.11	26.7	8.12
5	18	14	M	1.86	0.42	2.52	28.37	9.29	76.89	11.16	79.80	0.13	34.723	0.08	26.7	8.13
		15	D	2.48	0.98	3.64	35.11	9.60	78.85	12.09	83.44	0.13	34.741	0.13	26.3	8.12
		16	S	1.86	0.28	5.60	52.81	9.91	77.59	11.78	83.44	0.08	34.703	0.08	26.8	8.13
6	66	17	M	2.17	0.42	3.64	38.76	10.22	78.71	12.40	82.74	0.11	34.723	0.16	26.3	8.12
		18	D	3.10	1.12	5.88	43.54	9.60	80.39	12.71	87.38	0.15	34.768	0.16	25.2	8.11
		19	S	4.34	14.42	6.16	372.19	9.60	118.35	13.95	138.88	0.33	33.652	0.20	26.6	8.08
7	11	20	M	2.17	1.40	3.92	37.36	9.29	75.49	11.47	80.78	0.14	34.642	0.11	26.7	8.12
		21	D	2.79	1.54	4.48	39.05	9.29	76.61	12.09	82.60	0.10	34.733	0.10	26.4	8.12
		22	S	3.10	8.40	3.50	413.48	8.98	83.34	12.09	95.20	0.30	33.491	0.41	26.6	8.10
8	64	23	M	2.48	0.98	4.62	37.08	9.29	75.49	11.78	81.06	0.09	34.738	0.12	26.2	8.12
		24	D	2.79	1.26	8.26	42.70	9.60	77.45	12.40	86.94	0.11	34.806	0.14	24.7	8.11
		25	S	2.79	14.42	5.04	570.51	10.22	102.80	13.02	122.22	0.41	32.921	0.50	26.5	8.07
9	12	26	M	1.86	0.70	5.32	37.64	9.60	74.65	11.47	80.64	0.13	34.674	0.12	26.6	8.12
		27	D	2.17	0.70	4.78	33.71	9.60	75.63	11.78	81.06	0.10	34.703	0.14	26.5	8.12
		28	S	2.17	8.26	3.78	553.09	9.91	88.80	12.09	100.80	0.32	33.033	0.55	26.6	8.10
10	73	29	M	1.86	0.56	5.04	34.27	10.53	75.07	12.40	80.64	0.11	34.707	0.08	26.0	8.13
		30	D	2.48	1.54	6.44	45.22	9.60	77.87	12.09	85.82	0.12	34.806	0.15	24.5	8.11

TABLE 4. Water chemistry measurements (in µg/L) from waters in the vicinity of Fort Kamehameha sewage outfall extension collected on September 14, 1995. Abbreviations as follows: S=surfabe; M=mid; D=deep; BDL=below detection limit. For sampling locations, see Figure 1.

STATION	DEPTH (m)	SAMPLE NO.		PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	Si (µg/L)	DOP (µg/L)	DON (µg/L)	TDP (µg/L)	TDN (µg/L)	TURB (ntu)	SAL (o/oo)	CHL a (µg/L)	TEMP (deg C)	pH
		1	S	4.03	5.74	2.52	176.97	7.12	96.06	11.16	104.30	0.75	34.120	0.42	27.4	8.05
1	11	2	M	7.75	25.90	0.98	143.54	6.81	86.14	14.57	112.98	0.45	34.485	0.37	26.5	8.08
		3	D	3.41	1.68	1.82	64.89	6.50	76.15	9.92	81.62	0.61	34.727	0.23	26.0	8.09
		4	S	4.96	7.14	1.96	139.61	7.12	86.28	12.09	95.34	0.54	34.405	0.37	27.1	8.05
2	6	5	M	3.10	1.54	0.42	73.03	7.12	86.98	10.23	86.90	0.34	34.565	0.35	26.6	8.08
		6	D	3.10	1.54	1.12	57.87	6.81	91.46	9.92	94.06	0.29	34.688	0.23	26.4	8.08
		7	S	2.79	0.84	1.12	47.19	6.81	85.02	9.61	86.94	0.15	34.730	0.15	26.5	8.10
3	36	8	M	2.48	0.42	1.54	50.00	7.12	78.71	9.61	80.64	0.14	34.794	0.14	25.0	8.10
		9	D	2.48	0.28	1.40	51.12	6.81	77.73	9.30	79.38	0.10	34.836	0.14	24.0	8.09
		10	S	2.48	0.70	1.68	48.88	7.12	80.81	9.61	83.16	0.14	34.717	0.14	26.6	8.10
4	73	11	M	2.48	0.28	1.26	55.06	7.12	105.19	9.61	106.66	0.12	34.804	0.15	24.8	8.10
		12	D	2.17	0.28	0.70	47.47	7.12	84.68	9.30	85.82	0.10	34.820	0.11	23.5	8.09
		13	S	2.79	2.10	0.70	45.51	6.81	82.22	9.61	84.98	0.12	34.735	0.13	26.6	8.08
5	18	14	M	2.79	1.26	1.96	62.53	7.12	80.11	9.92	83.30	0.17	34.761	0.12	26.0	8.09
		15	D	2.48	0.42	0.98	48.60	6.50	77.59	8.99	78.96	0.15	34.865	0.12	24.5	8.09
		16	S	2.48	0.84	5.60	51.12	7.12	92.86	9.61	99.26	0.15	34.762	0.12	26.6	8.09
6	66	17	M	2.79	0.28	0.28	55.90	6.81	80.11	9.61	80.64	0.10	34.765	0.13	24.4	8.10
		18	D	2.48	0.28	1.26	51.97	6.50	81.65	8.99	83.16	0.12	34.816	0.13	23.5	8.09
		19	S	4.03	1.82	0.56	121.91	6.50	90.34	10.54	92.68	0.37	34.417	0.41	27.2	8.08
7	11	20	M	2.48	0.28	BDL	52.81	6.81	78.33	9.30	78.58	0.10	34.620	0.10	26.0	8.10
		21	D	2.79	0.84	2.38	49.16	6.50	74.51	9.30	77.70	0.11	34.744	0.12	25.3	8.10
		22	S	2.48	0.42	0.98	51.69	6.81	79.41	9.30	80.78	0.09	34.780	0.16	26.3	8.10
8	64	23	M	1.86	0.14	1.96	43.26	7.12	77.45	8.99	79.52	0.09	34.748	0.07	24.4	8.10
		24	D	2.17	0.28	0.98	50.28	6.50	78.71	8.68	79.94	0.10	34.838	0.15	23.8	8.09
		25	S	2.79	1.40	1.96	94.66	6.81	97.20	9.61	100.52	0.33	34.511	0.47	26.8	8.08
9	12	26	M	1.86	0.28	1.68	45.79	7.12	84.32	8.99	86.24	0.12	34.734	0.11	26.0	8.10
		27	D	2.48	1.40	2.10	46.07	6.50	82.78	8.99	86.24	0.10	34.753	0.08	26.0	8.10
		28	S	2.17	0.28	2.80	50.56	6.60	84.74	6.68	87.76	0.16	34.737	0.13	26.9	8.10
10	73	29	M	2.79	0.84	6.72	73.03	6.81	86.14	9.61	93.66	0.12	34.809	0.26	24.3	8.08
		30	D	2.79	0.70	7.98	66.29	7.12	84.74	9.92	93.38	0.10	34.842	0.20	23.7	8.08

TABLE 6. Water chemistry measurements (in µg/L) from waters in the vicinity of Fort Kamehameha sewage outfall extension collected on January 6, 1996. Samples were collected one day after rain and flooding impacted the area. Abbreviations as follows: S=surface; M=mid; D=deep; BDL=below detection limit. For sampling locations, see Figure 1.

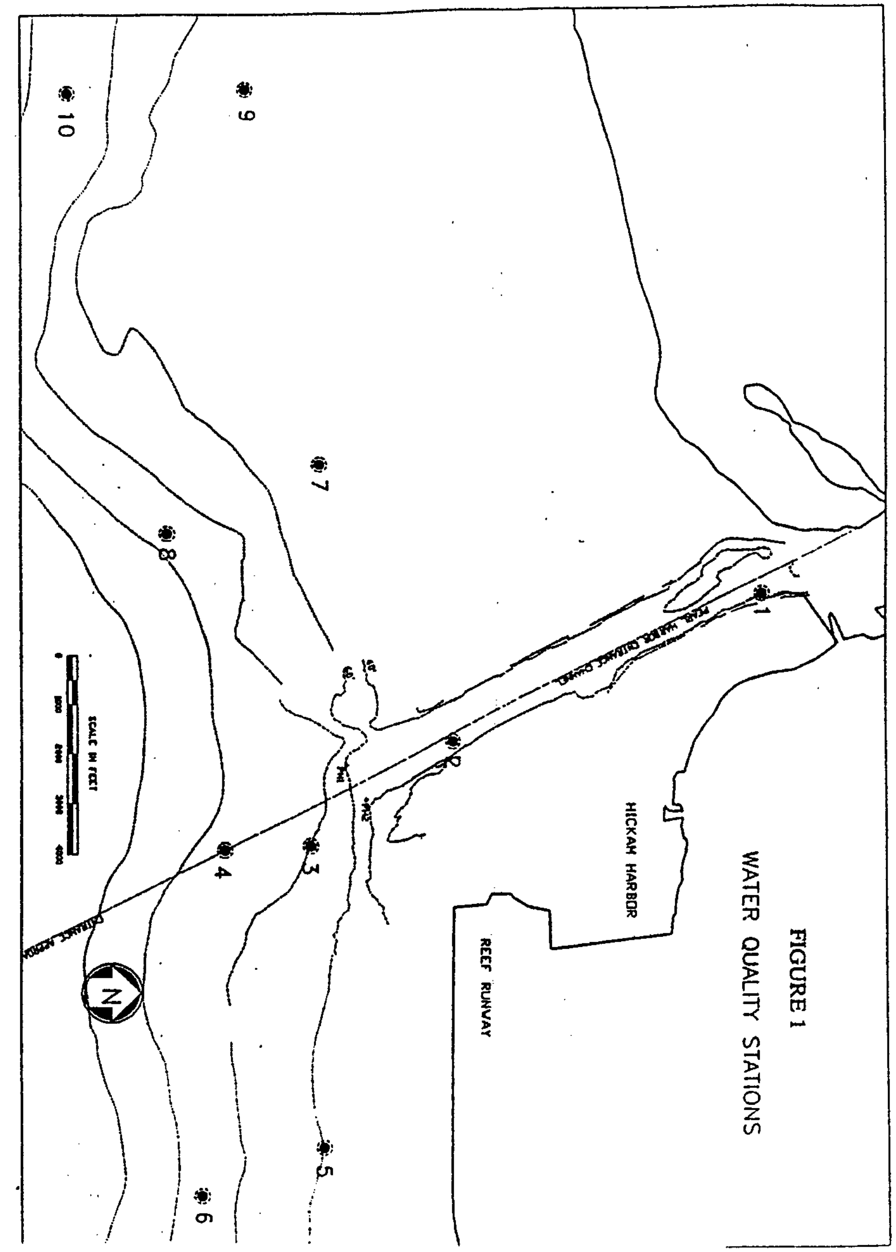
STATION	DEPTH (m)	SAMPLE NO.		PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	Si (µg/L)	DOP (µg/L)	DON (µg/L)	TDP (µg/L)	TDN (µg/L)	TURB (ntu)	SAL (o/oo)	CHL a (µg/L)	TEMP (deg C)	pH
1	11	1	S	4.03	3.36	1.96	1140.73	11.46	250.99	15.50	256.20	0.69	32.342	0.82	24.9	8.10
		2	M	8.99	22.40	13.30	235.96	10.84	181.38	19.84	217.00	0.25	34.359	0.29	25.3	8.11
		3	D	3.72	4.34	2.66	84.27	10.84	102.94	14.57	109.90	0.26	34.628	0.19	25.3	8.12
2	6	4	S	5.58	12.88	2.24	563.49	10.53	113.87	16.12	128.94	0.43	33.479	0.40	24.5	8.04
		5	M	4.03	4.90	1.68	72.47	9.29	89.36	13.33	95.90	0.18	34.595	0.19	25.3	8.11
		6	D	3.72	2.38	1.68	74.44	9.60	91.88	13.33	95.90	0.28	34.677	0.16	25.3	8.12
3	36	7	S	3.72	1.82	3.92	72.76	9.91	127.45	13.64	133.14	0.14	34.675	0.15	25.2	8.12
		8	M	3.41	0.98	2.80	46.35	9.60	93.84	13.02	97.58	0.13	34.773	0.13	25.2	8.13
		9	D	3.41	0.98	4.62	42.98	10.53	92.02	13.95	97.58	0.12	34.784	0.12	25.2	8.13
4	73	10	S	2.79	0.14	3.08	39.89	10.53	126.61	13.33	129.78	0.10	34.707	0.11	25.4	8.13
		11	M	3.10	0.70	1.96	44.38	10.22	111.07	13.33	113.68	0.08	34.818	0.12	24.5	8.13
		12	D	4.34	9.66	BDL	44.10	9.29	86.28	13.64	95.90	0.28	34.981	0.07	22.3	8.09
5	18	13	S	2.79	0.84	0.98	46.35	10.53	98.60	13.33	100.38	0.12	34.690	0.12	25.3	8.14
		14	M	2.79	0.14	0.42	55.08	10.53	94.82	13.33	95.34	0.10	34.721	0.13	25.3	8.13
		15	D	3.41	2.24	2.24	57.02	11.15	94.82	14.57	99.26	0.27	34.800	0.22	25.3	8.13
6	66	16	S	2.48	0.14	1.12	50.56	10.22	84.74	12.71	85.96	0.10	34.732	0.11	24.9	8.14
		17	M	2.48	0.14	0.70	36.52	10.22	93.28	12.71	94.08	0.11	34.726	0.12	24.9	8.15
		18	D	4.03	7.28	1.12	44.94	8.67	81.51	12.71	89.88	0.10	34.947	0.10	23.5	8.11
7	11	19	S	4.65	12.04	1.96	247.19	9.91	106.73	14.67	120.68	0.28	34.231	0.27	24.9	8.09
		20	M	3.10	2.66	3.22	53.93	10.22	88.52	13.33	94.36	0.10	34.753	0.12	25.0	8.13
		21	D	3.10	1.82	0.84	46.91	10.22	88.60	13.33	91.42	0.16	34.740	0.11	25.0	8.13
8	64	22	S	3.41	2.24	3.22	56.74	10.22	103.92	13.64	109.34	0.12	34.672	0.13	25.2	8.13
		23	M	3.41	2.10	3.22	43.54	9.60	92.58	13.02	97.86	0.09	34.656	0.11	24.9	8.13
		24	D	2.79	2.94	1.12	45.51	9.91	87.40	12.71	91.42	0.19	34.880	0.09	23.6	8.12
9	12	25	S	5.58	12.88	3.36	226.69	9.91	127.59	16.50	143.78	0.22	34.191	0.07	24.9	8.07
		26	M	3.10	2.66	2.38	71.07	9.91	94.26	13.02	99.26	0.14	34.616	0.14	25.0	8.12
		27	D	3.41	2.66	1.54	63.76	10.53	202.67	13.95	206.78	0.13	34.624	0.14	25.0	8.13
10	73	28	S	2.48	1.40	3.08	65.17	10.53	118.21	13.02	122.64	0.12	34.710	0.12	25.2	8.14
		29	M	3.10	3.08	3.92	63.76	9.91	111.49	13.02	116.44	0.07	34.875	0.12	25.0	8.13
		30	D	3.41	5.88	3.64	38.20	9.60	110.65	13.02	120.12	0.09	34.923	0.09	23.2	8.11

TABLE 7. Water chemistry measurements (in µg/L) from waters in the vicinity of Fort Kamehameha sewage outfall extension collected on February 7, 1996. Abbreviations as follows: S=surface; M=mid; D=deep. For sampling locations, see Figure 1.

STATION	DEPTH (m)	SAMPLE NO.		PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	Si (µg/L)	DOP (µg/L)	DON (µg/L)	TDP (µg/L)	TDN (µg/L)	TURB (ntu)	SAL (o/oo)	CHL a (µg/L)	TEMP (deg C)	pH
1	11	1	S	2.48	5.18	1.96	625.28	11.46	112.61	13.95	119.70	0.30	33.503	1.12	25.5	8.17
		2	M	8.37	25.62	4.62	241.01	9.91	104.90	18.29	135.10	0.24	34.319	0.60	24.9	8.17
		3	D	4.03	2.38	5.60	71.35	8.98	94.68	13.02	102.62	0.21	34.722	0.21	24.6	8.17
2	6	4	S	7.44	25.20	2.52	442.42	9.29	109.53	16.74	137.20	0.30	33.826	0.85	25.3	8.15
		5	M	2.79	0.84	2.24	101.12	8.98	91.74	11.78	94.78	0.17	34.787	0.19	24.9	8.18
		6	D	2.79	0.70	2.52	57.58	8.98	90.90	11.78	94.08	0.16	34.785	0.16	24.5	8.18
3	36	7	S	5.27	8.12	2.38	145.79	8.36	86.70	13.64	97.16	0.20	34.337	0.30	25.3	8.17
		8	M	2.48	0.84	3.08	53.09	9.29	84.60	11.78	88.48	0.10	34.789	0.17	24.4	8.18
		9	D	2.48	0.98	2.10	41.57	9.29	89.36	11.78	92.40	0.12	34.799	0.15	24.4	8.18
4	73	10	S	3.41	0.56	1.54	78.37	8.67	94.96	12.09	97.02	0.17	34.536	0.27	25.2	8.18
		11	M	2.48	0.70	1.68	48.03	9.60	96.64	12.09	98.98	0.15	34.812	0.16	24.3	8.18
		12	D	2.48	1.40	2.10	50.84	8.98	105.89	11.47	109.34	0.12	34.834	0.16	24.1	8.18
5	18	13	S	4.03	4.48	2.66	92.14	8.05	108.55	12.09	115.64	0.18	34.488	0.17	25.2	8.16
		14	M	2.79	1.54	1.54	49.16	9.29	115.41	12.09	118.44	0.13	34.723	0.19	24.6	8.18
		15	D	3.41	2.94	2.10	54.78	8.98	109.39	12.40	114.38	0.14	34.740	0.17	24.5	8.17
6	66	16	S	3.72	1.82	2.24	108.99	9.81	108.41	13.64	112.42	0.17	34.471	0.31	25.3	8.18
		17	M	2.79	2.62	4.76	57.30	10.22	105.19	13.02	112.42	0.12	34.795	0.16	24.3	8.18
		18	D	3.10	1.96	6.30	83.37	10.84	110.65	13.95	118.86	0.12	34.678	0.13	23.8	8.18
7	11	19	S	5.27	7.00	4.48	83.71	9.29	107.01	14.57	118.44	0.15	34.453	0.12	25.3	8.17
		20	M	2.79	1.40	2.80	57.87	9.29	108.41	12.09	112.56	0.13	34.704	0.15	25.0	8.18
		21	D	3.41	1.82	3.50	67.42	9.91	112.89	13.33	118.16	0.14	34.765	0.10	24.5	8.15
8	64	22	S	2.17	0.70	3.50	51.40	9.60	111.63	11.78	115.78	0.14	34.711	0.09	25.1	8.19
		23	M	1.86	0.70	3.08	51.69	10.22	131.52	12.09	135.24	0.12	34.800	0.11	24.4	8.19
		24	D	2.48	1.26	3.64	56.46	9.60	125.63	12.09	130.46	0.12	34.868	0.12	23.8	8.18
9	12	25	S	2.48	1.68	3.92	47.47	9.91	139.78	12.40	145.32	0.14	34.712	0.11	25.1	8.19
		26	M	2.48	0.84	2.80	48.03	9.60	130.40	12.09	133.98	0.13	34.741	0.10	24.6	8.19
		27	D	2.48	1.54	2.94	51.69	9.60	142.02	12.09	146.44	0.14	34.760	0.13	24.4	8.18
10	73	28	S	2.17	0.42	3.08	52.25	9.60	130.68	11.78	134.12	0.19	34.705	0.08	25.0	8.20
		29	M	2.48	0.14	4.48	48.03	9.29	112.33	11.78	116.90	0.13	34.806	0.11	24.5	8.19
		30	D	2.17	0.56	3.22	59.83	9.60	116.53	11.78	120.26	0.22	34.829	0.11	24.4	8.18

TABLE 8. Geometric means of water chemistry measurements from waters in the vicinity of Fort Kamehameha sewage outfall extension collected during seven surveys conducted between February 27, 1995 and February 7, 1996. Abbreviations as follows: S=surface; M=mid; D=deep. For sampling locations, see Figure 1.

STATION	DEPTH (m)	SAMPLE NO.	PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	Si (µg/L)	DOP (µg/L)	DON (µg/L)	TDP (µg/L)	TON (µg/L)	TURB (ntu)	SAL (o/oo)	CHL a (µg/L)	TEMP (deg C)	pH
1	11	1 S	3.15	5.58	1.72	613.83	8.34	112.30	12.49	122.01	0.50	33.084	0.77	25.6	8.12
		2 M	5.00	8.73	1.59	169.84	8.92	95.36	14.43	109.95	0.29	34.484	0.50	25.4	8.13
		3 D	3.33	2.57	2.27	89.74	7.77	85.86	11.25	90.94	0.35	34.649	0.35	25.3	8.13
2	6	4 S	3.97	7.40	1.24	176.86	7.53	95.82	12.01	106.49	0.31	34.226	0.39	25.3	8.10
		5 M	3.01	2.59	1.31	71.53	7.82	86.41	11.17	90.91	0.21	34.661	0.24	25.4	8.12
		6 D	2.83	2.30	1.59	63.21	7.98	86.30	11.06	90.92	0.23	34.694	0.20	25.3	8.13
3	36	7 S	2.66	1.83	1.55	72.05	7.89	92.24	10.83	96.65	0.15	34.628	0.21	25.4	8.14
		8 M	2.25	0.65	1.87	53.97	8.50	88.79	10.92	89.20	0.11	34.738	0.19	25.0	8.14
		9 D	2.12	0.71	1.69	48.40	8.59	87.26	10.96	90.32	0.11	34.749	0.19	24.7	8.14
4	73	10 S	2.51	0.86	1.86	63.20	8.35	99.18	11.00	102.97	0.13	34.647	0.19	25.4	8.14
		11 M	1.96	0.52	1.38	46.79	8.52	94.50	10.68	98.75	0.12	34.755	0.15	24.7	8.15
		12 D	2.18	1.04	1.49	45.90	7.97	87.46	10.32	91.19	0.13	34.806	0.14	23.6	8.13
5	18	13 S	2.20	1.51	1.64	56.77	7.91	92.72	10.30	96.41	0.13	34.665	0.16	25.5	8.14
		14 M	1.89	0.70	1.48	52.48	7.81	89.15	9.83	92.00	0.14	34.716	0.15	25.2	8.14
		15 D	2.71	1.51	2.31	52.82	8.11	89.57	10.89	94.44	0.15	34.747	0.17	24.8	8.14
6	66	16 S	1.97	0.65	2.16	60.02	8.15	89.06	10.36	92.87	0.12	34.675	0.15	25.4	8.15
		17 M	2.03	0.50	1.37	47.12	8.54	87.86	10.80	90.62	0.11	34.727	0.15	24.7	8.15
		18 D	1.93	1.05	1.92	46.77	8.11	81.85	10.45	86.00	0.12	34.790	0.16	23.7	8.14
7	11	19 S	3.41	3.92	1.93	150.77	7.87	95.06	11.52	102.86	0.24	34.272	0.30	25.4	8.12
		20 M	2.39	1.23	2.50	60.05	7.94	83.53	10.51	87.28	0.13	34.665	0.19	25.3	8.14
		21 D	2.51	1.46	2.20	51.83	8.09	85.63	10.74	89.63	0.13	34.721	0.15	25.0	8.14
8	64	22 S	1.99	1.34	2.25	86.97	8.03	92.28	10.24	97.30	0.15	34.441	0.21	25.3	8.14
		23 M	2.06	0.61	2.58	49.06	8.45	88.74	10.62	92.35	0.11	34.738	0.14	24.7	8.15
		24 D	2.10	0.81	2.03	49.44	8.33	87.78	10.56	91.72	0.13	34.783	0.16	24.0	8.14
9	12	25 S	2.58	2.69	2.58	122.84	7.89	102.40	10.62	109.95	0.20	34.258	0.23	25.3	8.12
		26 M	1.95	0.68	2.15	52.66	7.91	89.78	9.91	92.87	0.13	34.687	0.15	25.1	8.14
		27 D	2.19	1.11	2.04	52.11	8.24	105.73	10.50	109.49	0.13	34.697	0.16	25.0	8.14
10	73	28 S	2.07	0.85	2.72	75.73	8.36	95.07	10.47	99.68	0.15	34.468	0.16	25.4	8.15
		29 M	2.03	0.66	3.12	50.86	8.33	87.90	10.44	92.45	0.10	34.759	0.14	24.7	8.15
		30 D	2.28	0.92	3.65	54.71	8.18	87.30	10.56	92.90	0.11	34.792	0.14	24.1	8.14



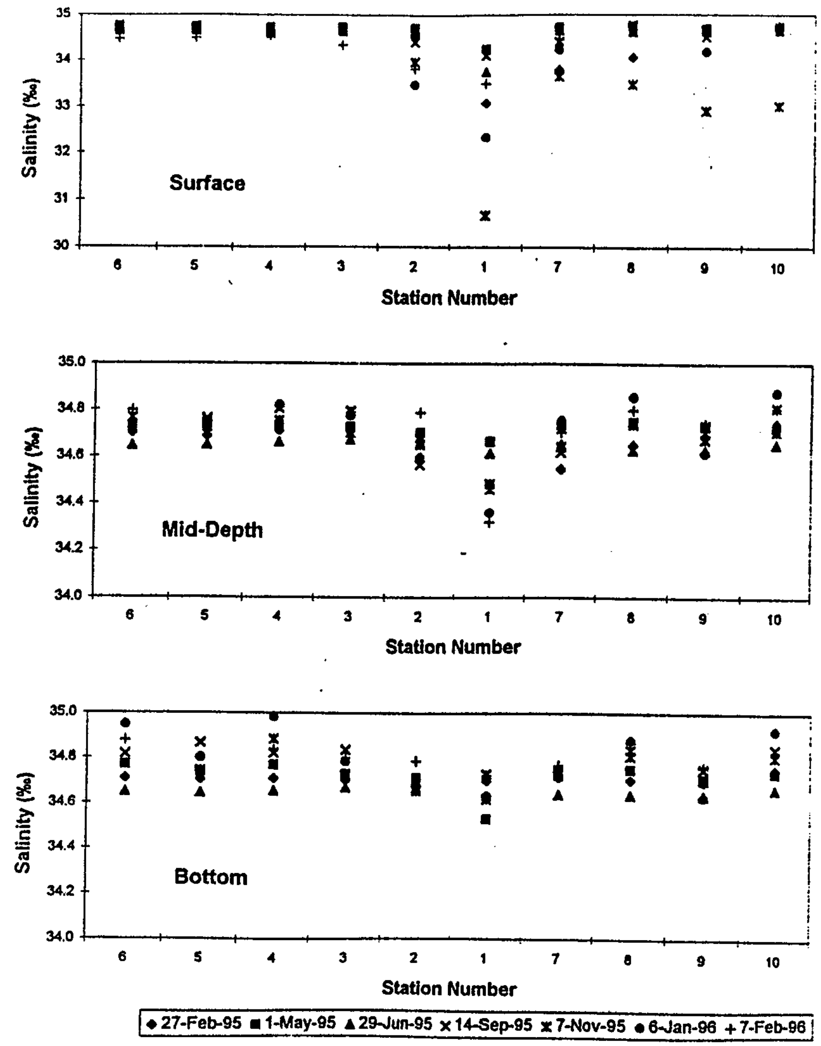


FIGURE 2. Scatter plots showing measurements of salinity in surface, mid-depth and bottom samples collected at ten stations over the course of one year in the vicinity of the Fort Kamehameha sewage outfall extension. Note y-axis scale change for surface samples. Station numbers are arranged in an approximate East to West orientation. For station locations, see Figure 1.

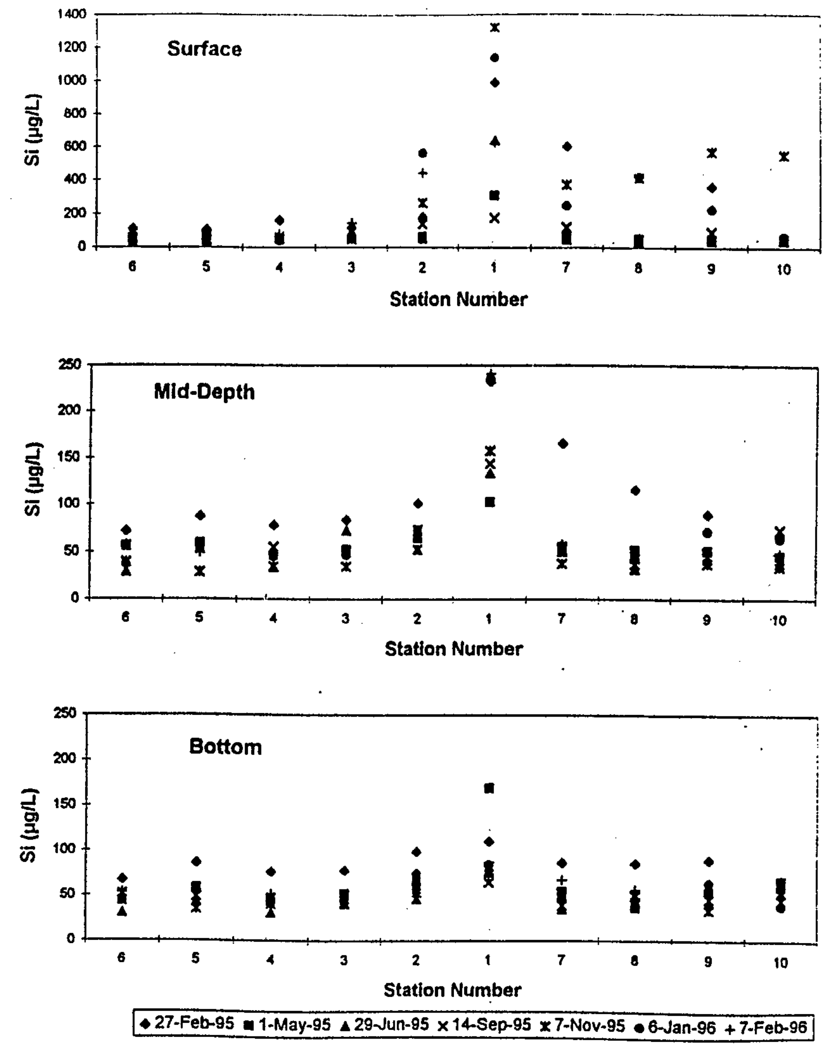


FIGURE 3. Scatter plots showing the concentration of silicate in surface, mid-depth and bottom samples collected at ten stations over the course of one year in the vicinity of the Fort Kamehameha sewage outfall extension. Note y-axis scale change for surface samples. Station numbers are arranged in an approximate East to West orientation. For station locations, see Figure 1.

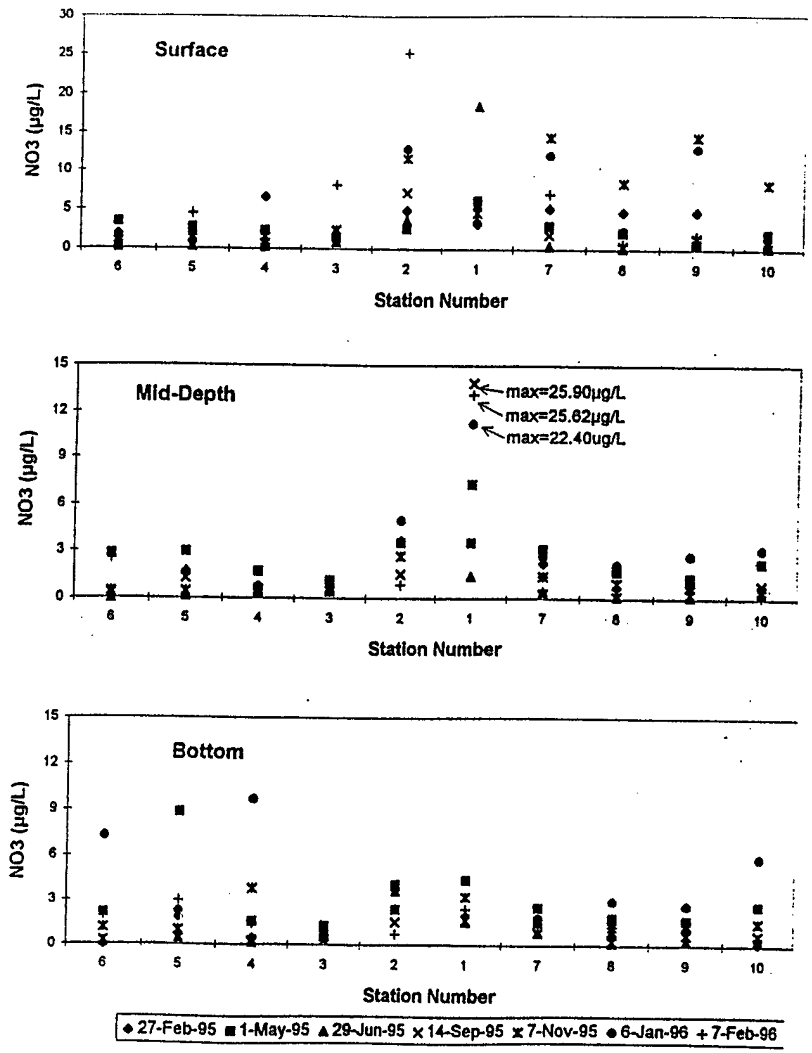


FIGURE 4. Scatter plots showing the concentration of nitrate in surface, mid-depth and bottom samples collected at ten stations over the course of one year in the vicinity of the Fort Kamehameha sewage outfall extension. Note y-axis scale change for surface samples. Station numbers are arranged in an approximate East to West orientation. For station locations, see Figure 1.

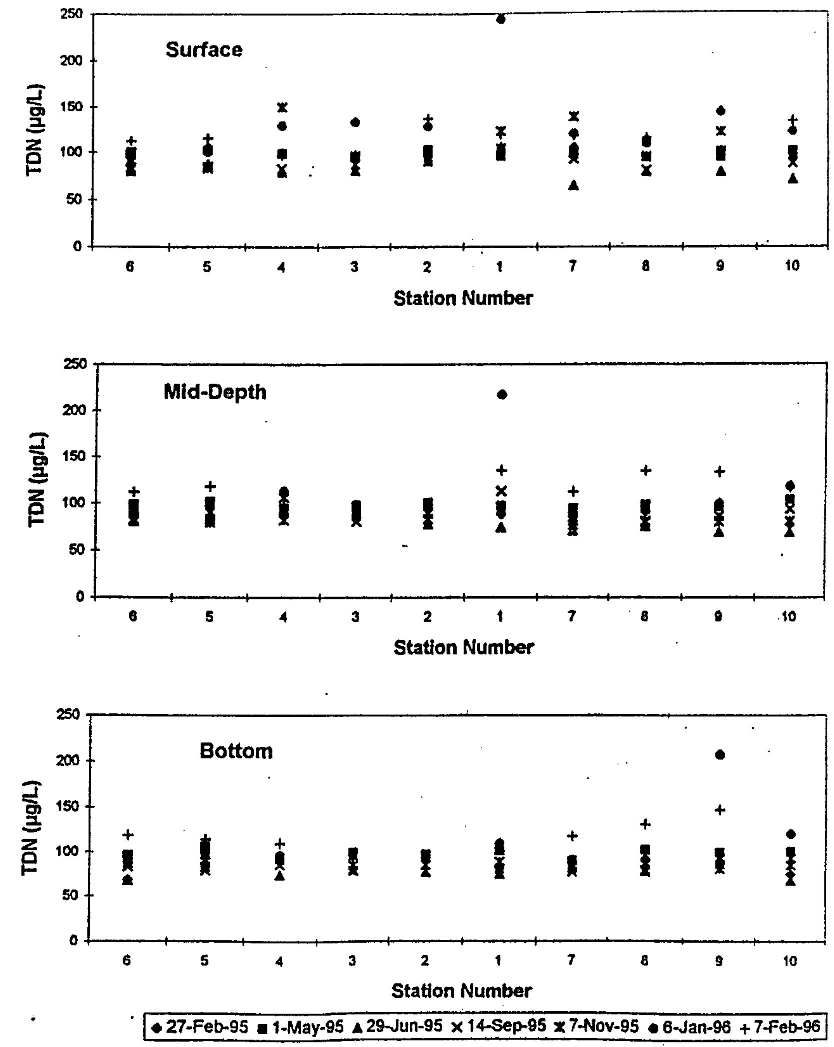


FIGURE 5. Scatter plots showing the concentration of total dissolved nitrogen in surface, mid-depth and bottom samples collected at ten stations over the course of one year in the vicinity of the Fort Kamehameha sewage outfall extension. Station numbers are arranged in an approximate East to West orientation. For station locations, see Figure 1.

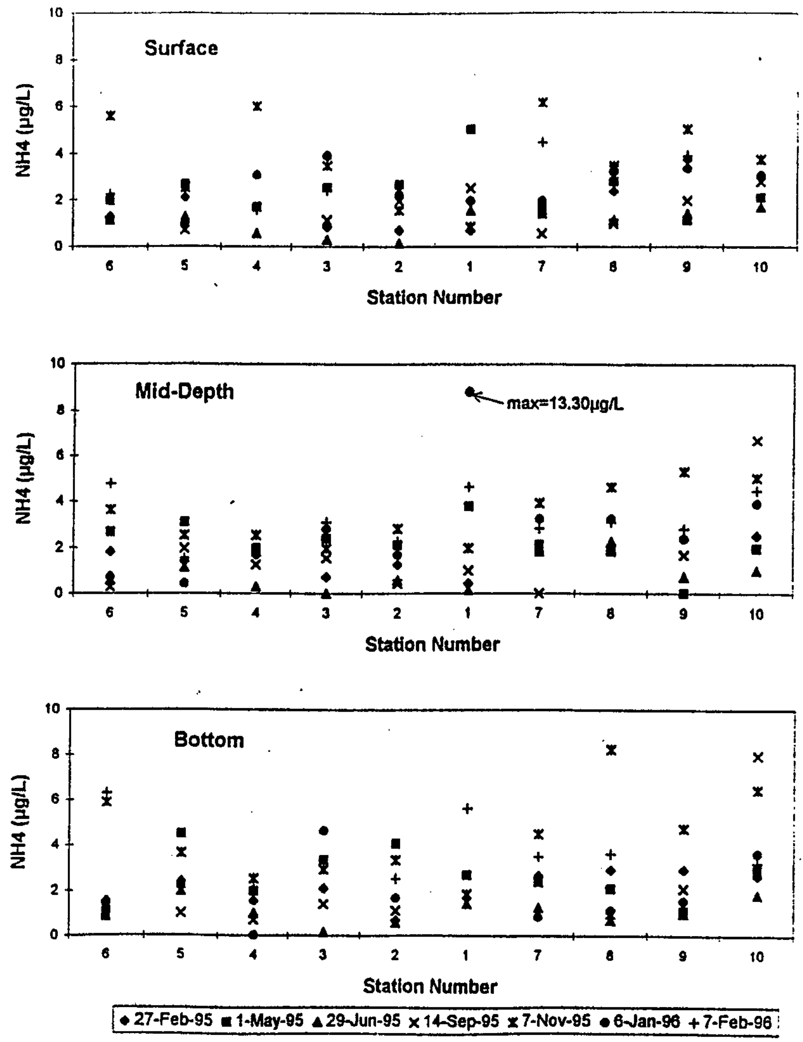


FIGURE 6. Scatter plots showing the concentration of ammonium in surface, mid-depth and bottom samples collected at ten stations over the course of one year in the vicinity of the Fort Kamehameha sewage outfall extension. Station numbers are arranged in an approximate East to West orientation. For station locations, see Figure 1.

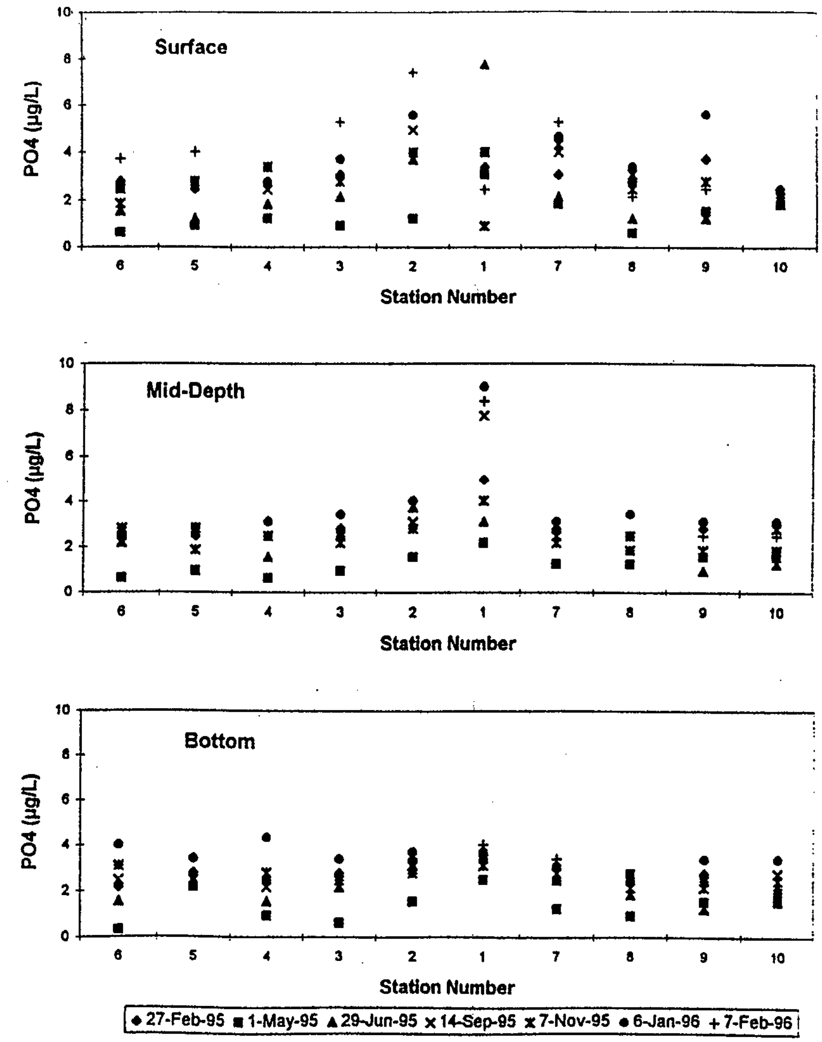


FIGURE 7. Scatter plots showing the concentration of phosphate in surface, mid-depth and bottom samples collected at ten stations over the course of one year in the vicinity of the Fort Kamehameha sewage outfall extension. Station numbers are arranged in an approximate East to West orientation. For station locations, see Figure 1.

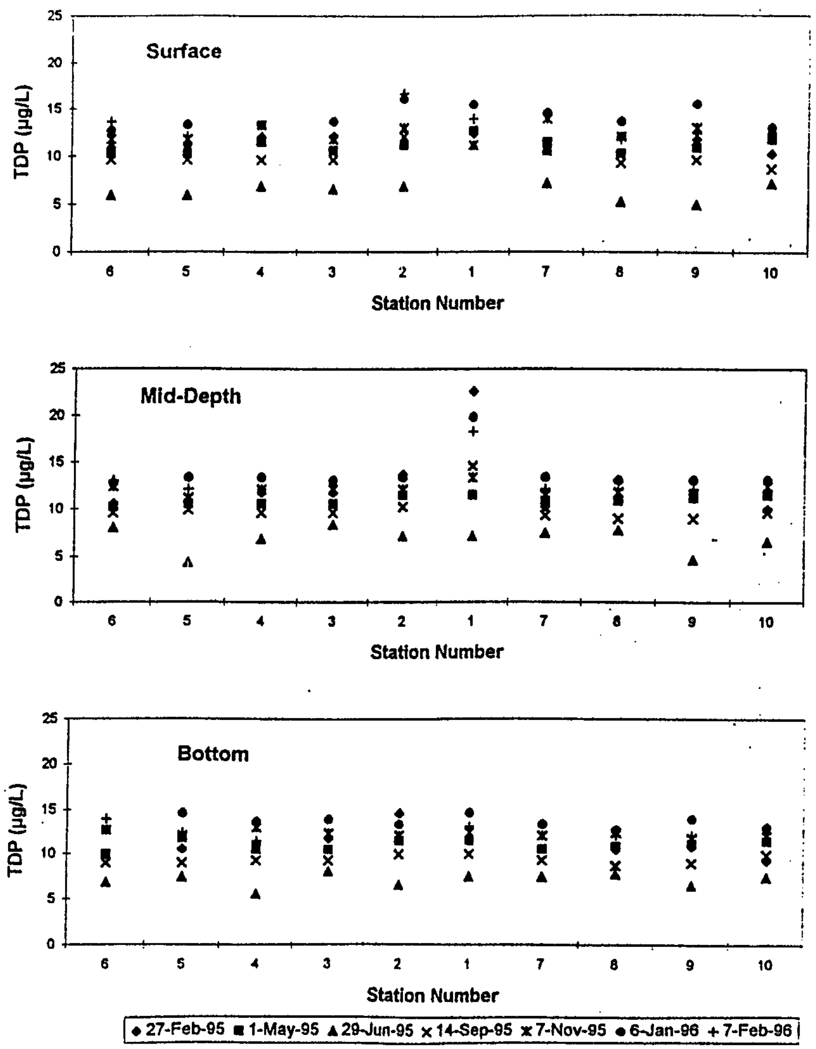


FIGURE 8. Scatter plots showing the concentration of total dissolved phosphorus in surface, mid-depth and bottom samples collected at ten stations over the course of one year in the vicinity of the Fort Kamehameha sewage outfall extension. Station numbers are arranged in an approximate East to West orientation. For station locations, see Figure 1.

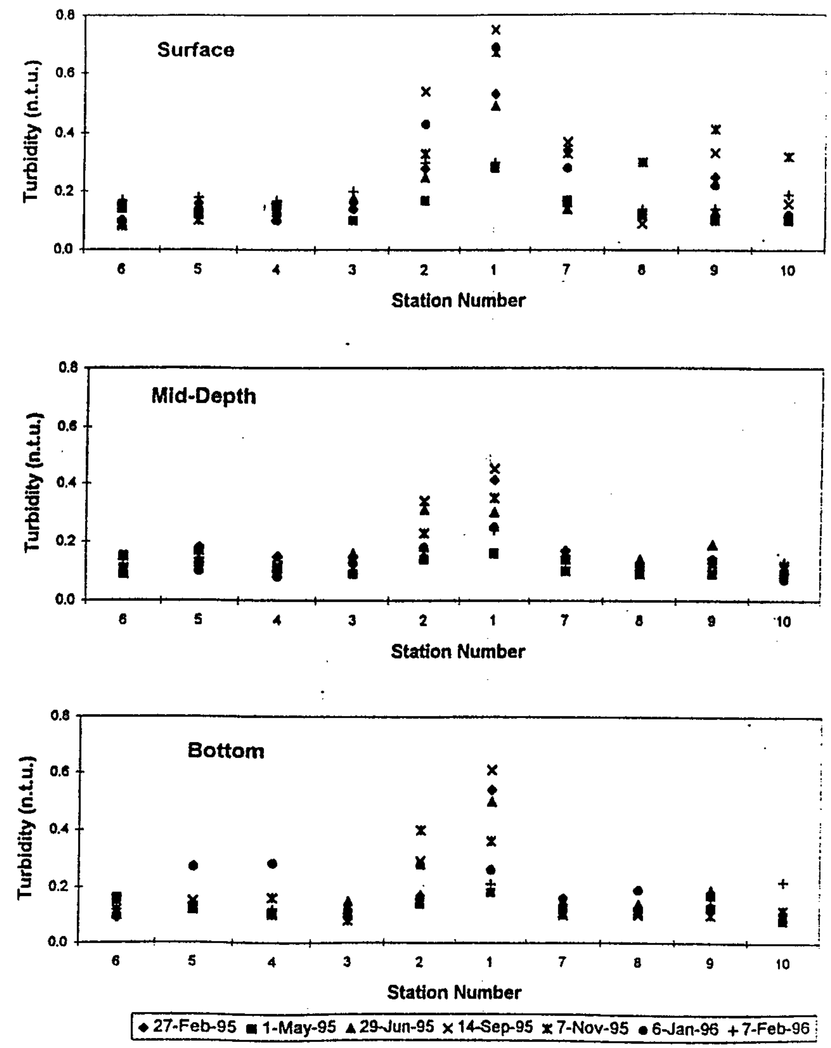


FIGURE 9. Scatter plots showing measurements of tubidity in surface, mid-depth and bottom samples collected at ten stations over the course of one year in the vicinity of the Fort Kamehameha sewage outfall extension. Station numbers are arranged in an approximate East to West orientation. For station locations, see Figure 1.

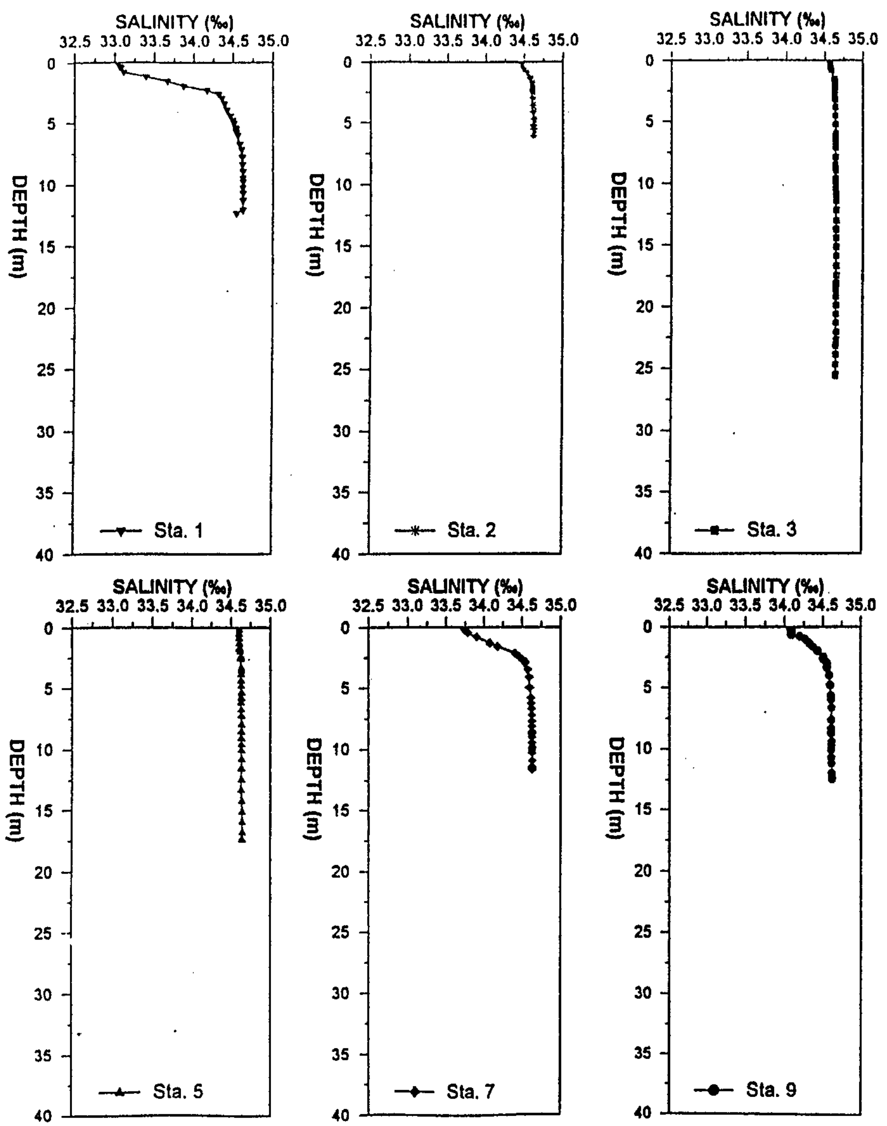


FIGURE 10. Vertical profiles of salinity measured at six inshore stations on February 27, 1995 near the Fort Kamehameha sewage outfall extension. For station locations, see Figure 1.

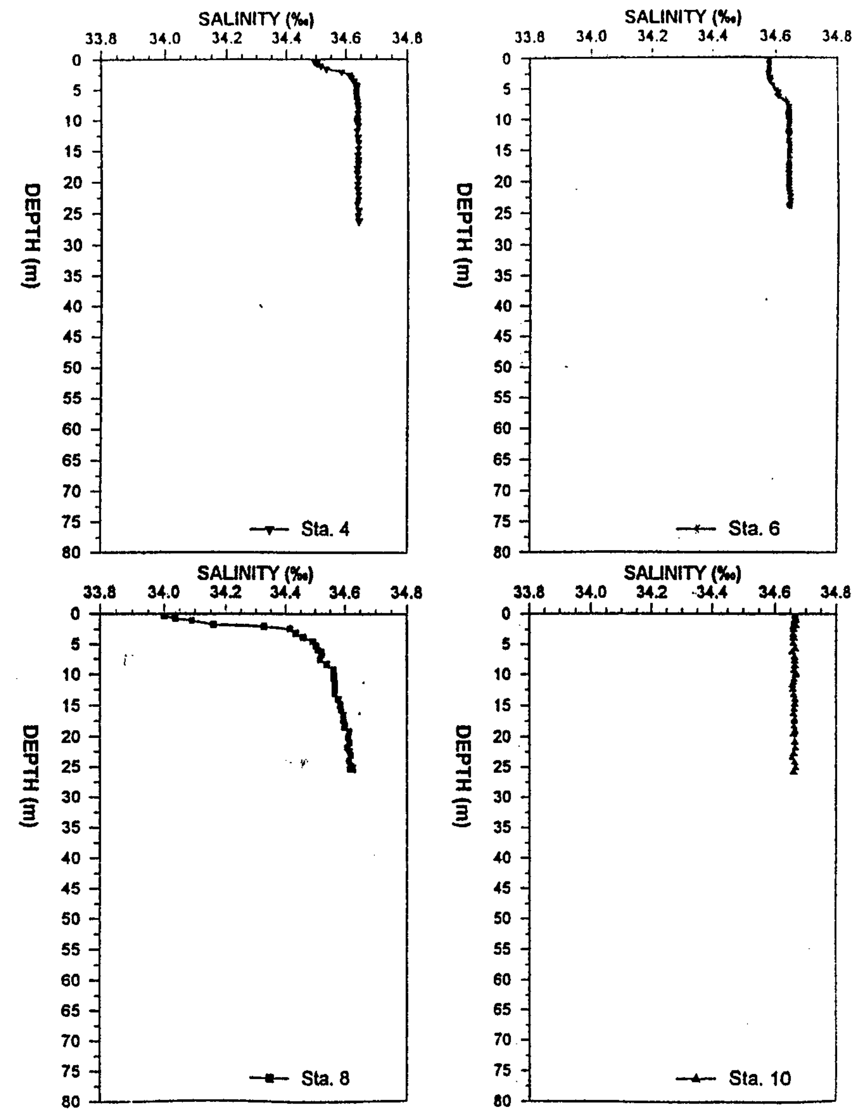


FIGURE 11. Vertical profiles of salinity measured at four offshore stations on February 27, 1995 near the Fort Kamehameha sewage outfall extension. For station locations, see Figure 1.

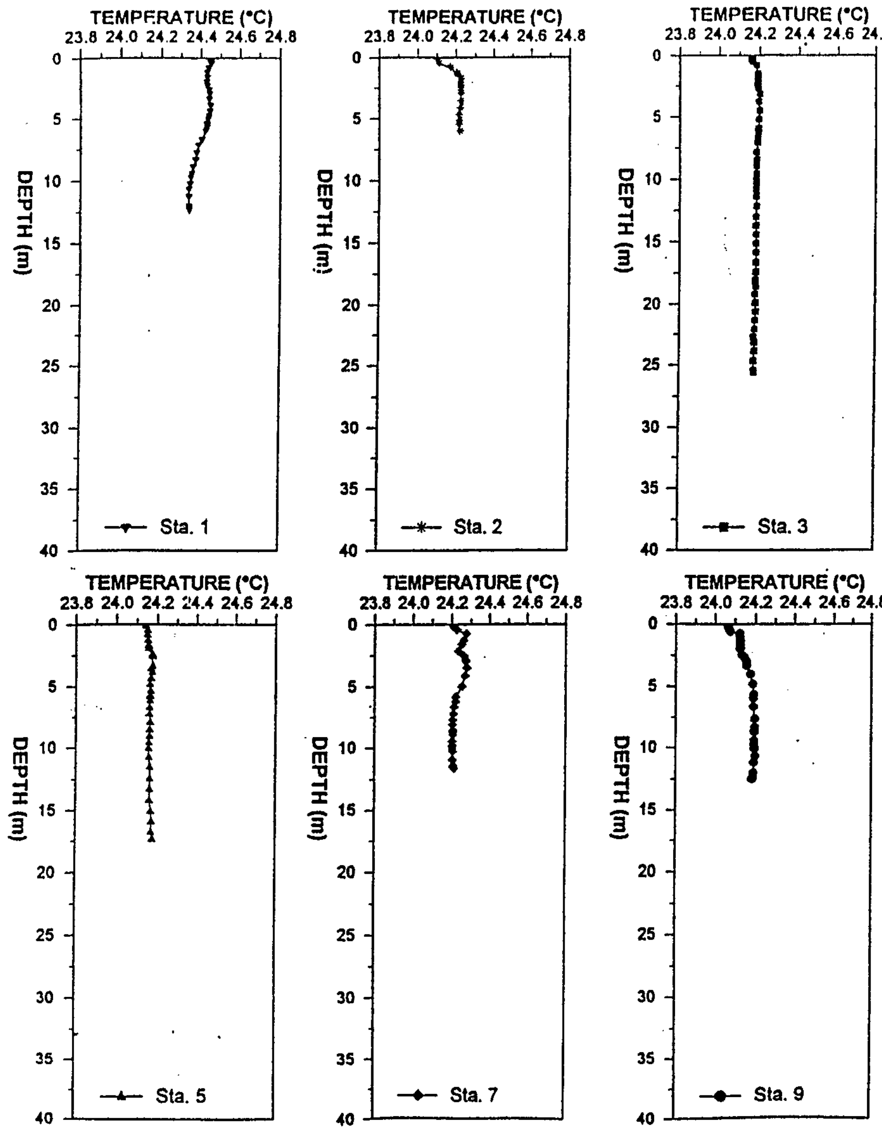


FIGURE 12. Vertical profiles of temperature measured at six inshore stations on February 27, 1995 near the Fort Kamehameha sewage outfall extension. For station locations, see Figure 1.

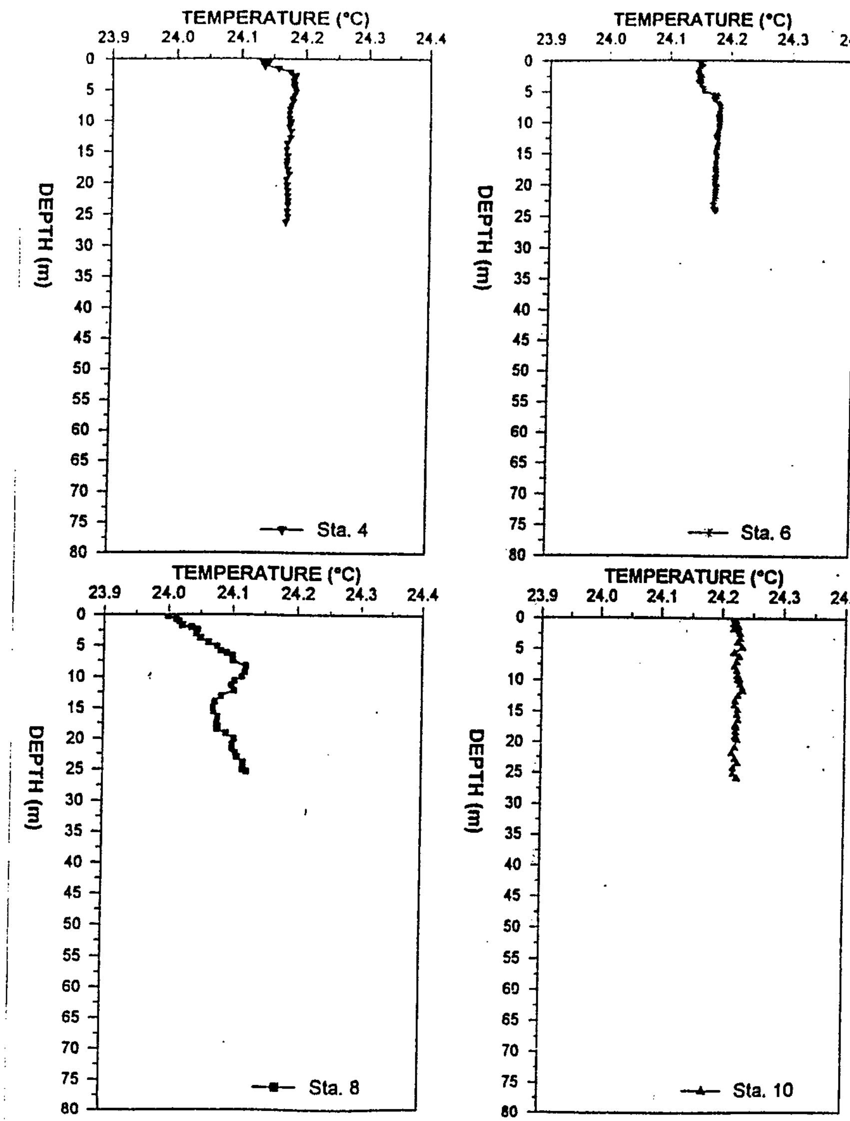


FIGURE 13. Vertical profiles of temperature measured at four offshore stations on February 27, 1995 near the F Kamehameha sewage outfall extension. For station locations, see Figure 1.

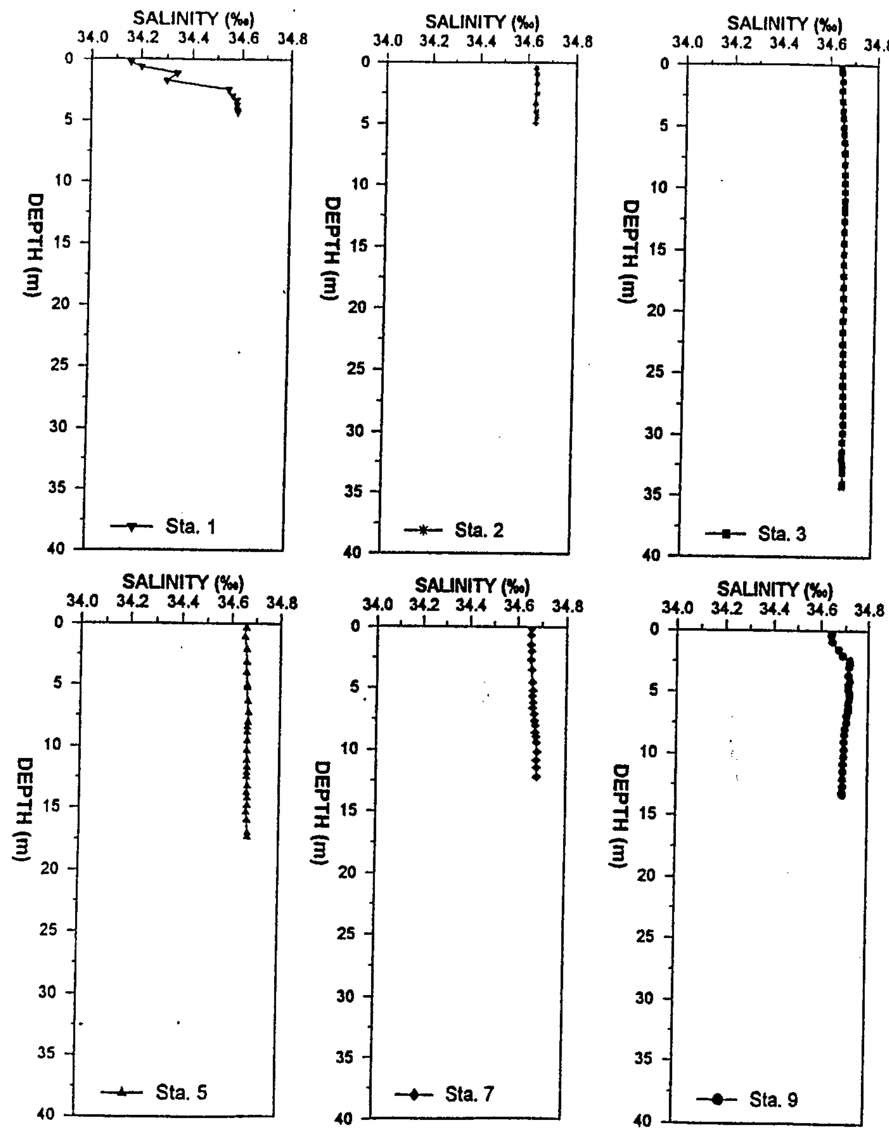


FIGURE 14. Vertical profiles of salinity measured at six inshore stations on May 1, 1995 near the Fort Kamehameha sewage outfall extension. For station locations, see Figure 1.

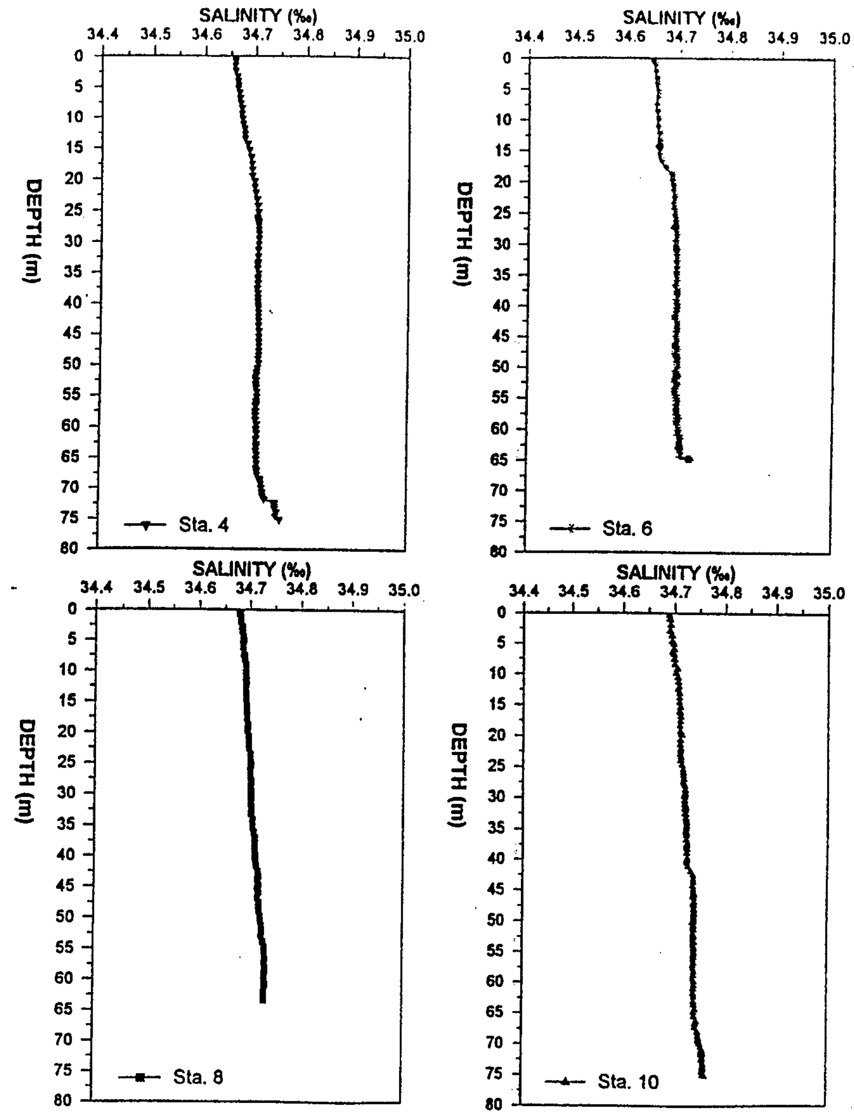


FIGURE 15. Vertical profiles of salinity measured at four offshore stations on May 1, 1995 near the Fort Kamehameha sewage outfall extension. For station locations, see Figure 1.

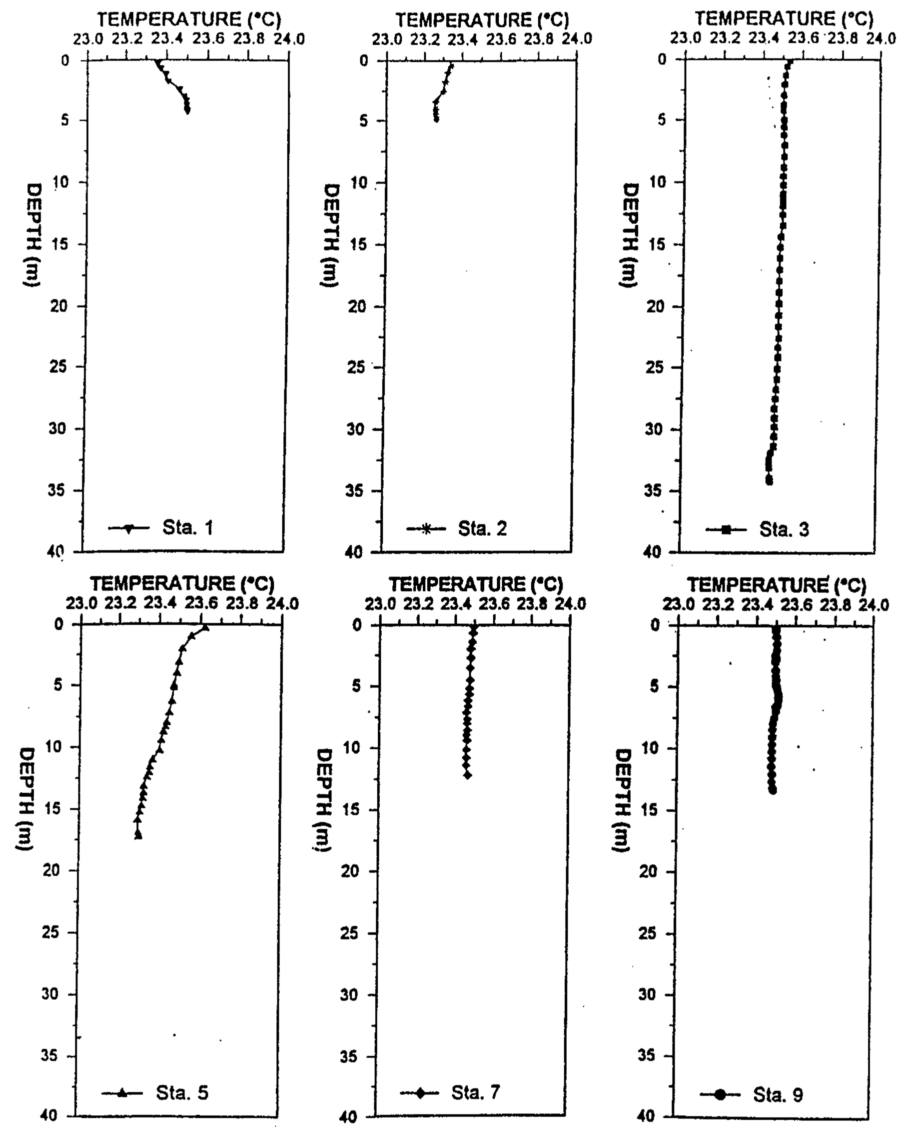


FIGURE 16. Vertical profiles of temperature measured at six inshore stations on May 1, 1995 near the Fort Kamehameha sewage outfall extension. For station locations, see Figure 1.

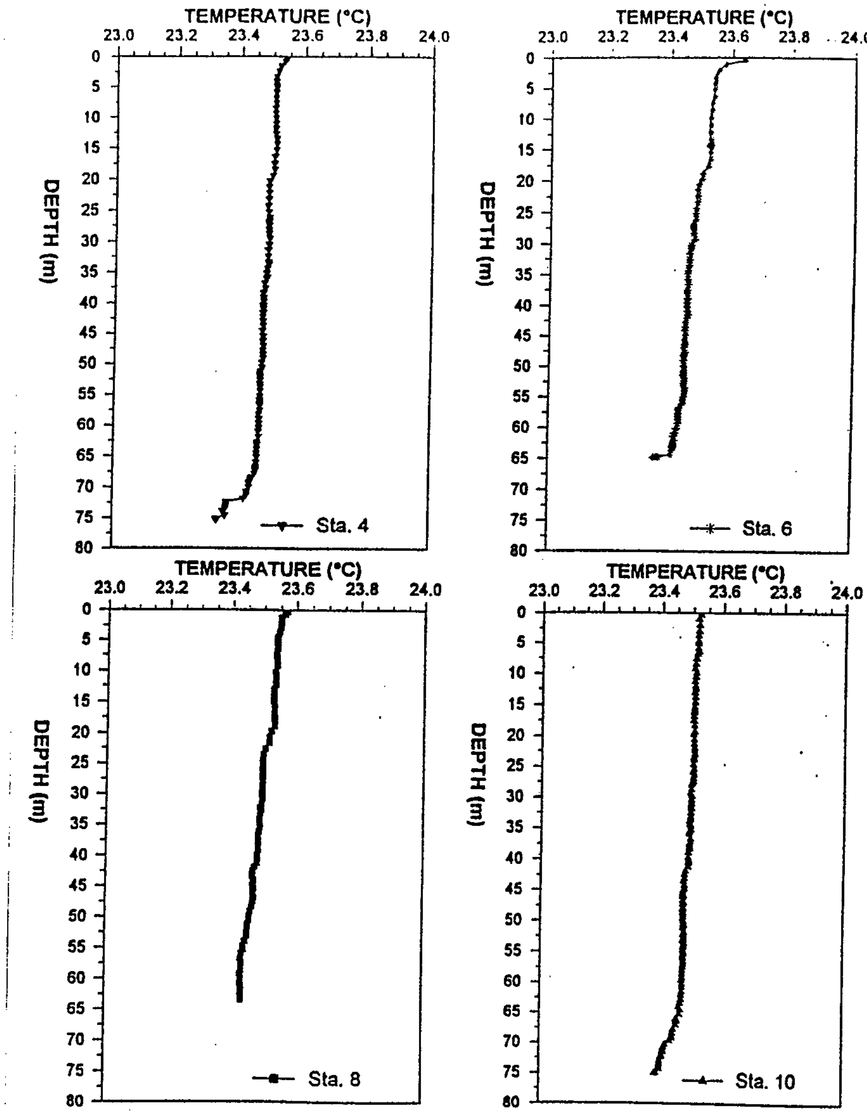


FIGURE 17. Vertical profiles of temperature measured at four offshore stations on May 1, 1995 near the Fort Kamehameha sewage outfall extension. For station locations, see Figure 1.

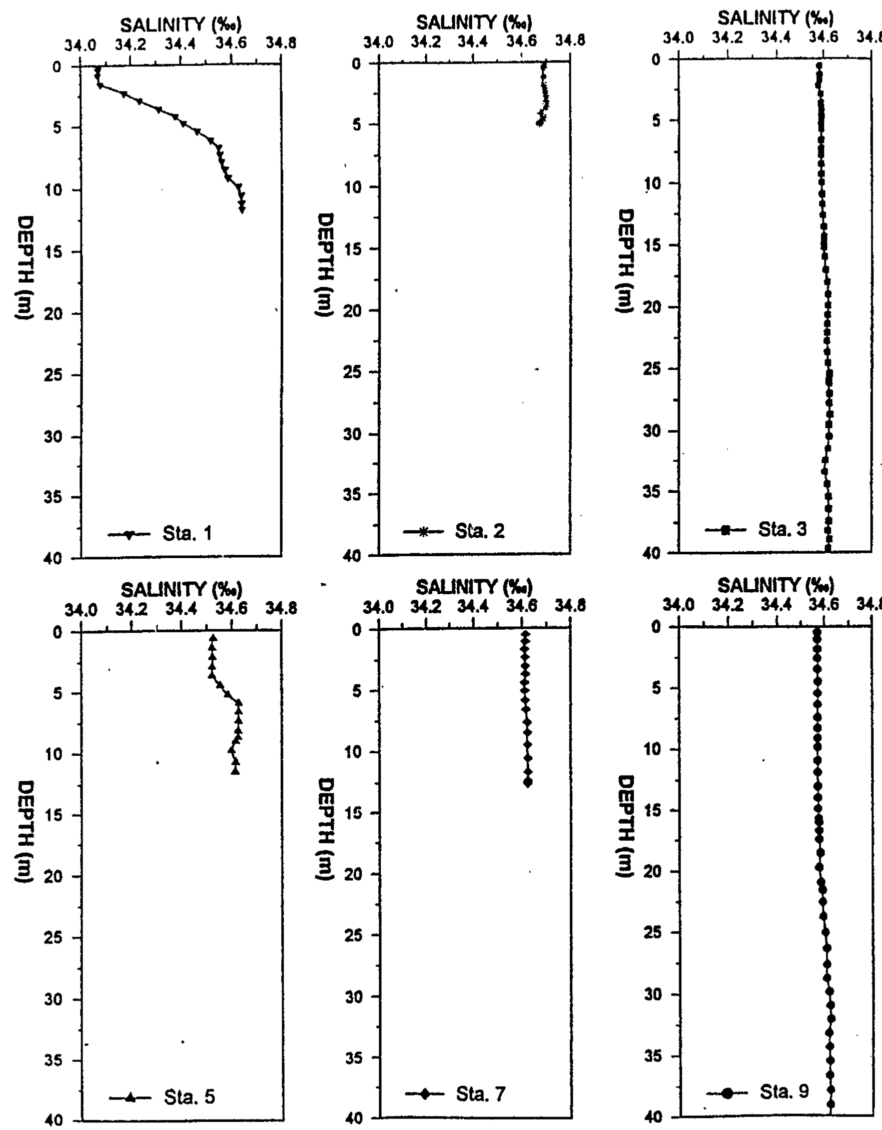


FIGURE 18. Vertical profiles of salinity measured at six inshore stations on July 14, 1995 near the Fort Kamehameha sewage outfall extension. For station locations, see Figure 1.

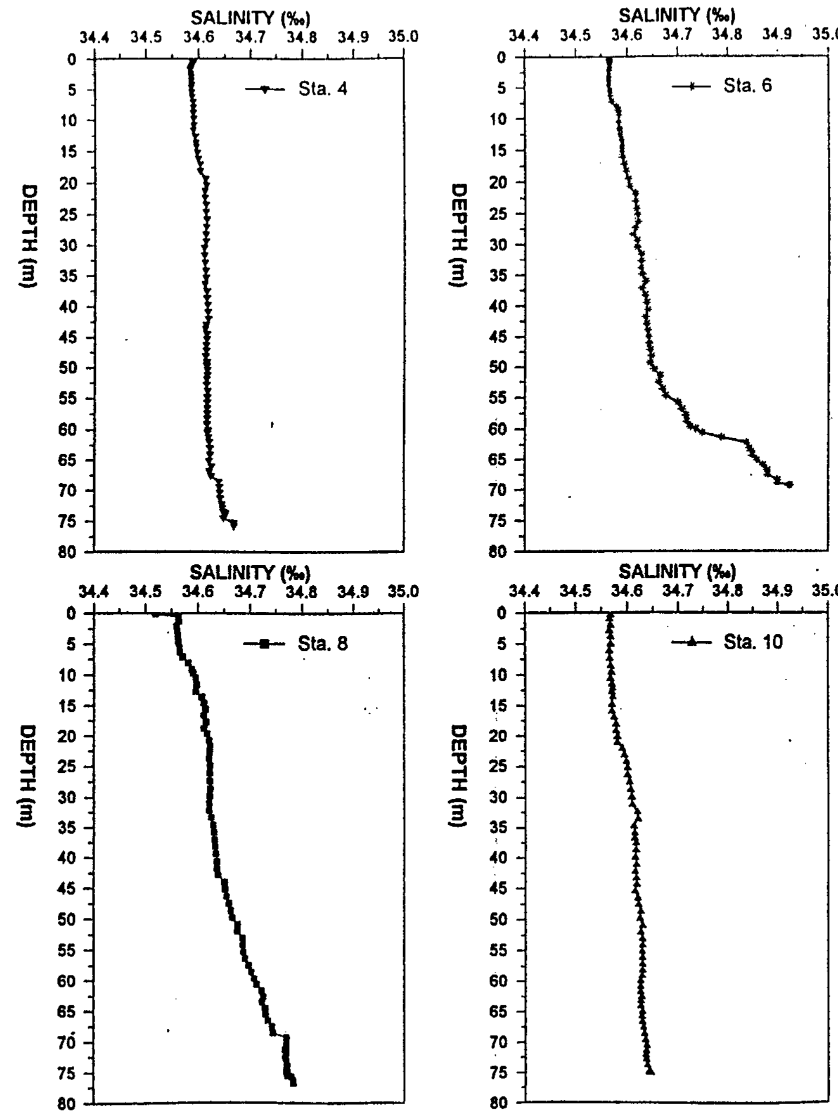


FIGURE 19. Vertical profiles of salinity measured at four offshore stations on July 14, 1995 near the Fort Kamehameha sewage outfall extension. For station locations, see Figure 1.

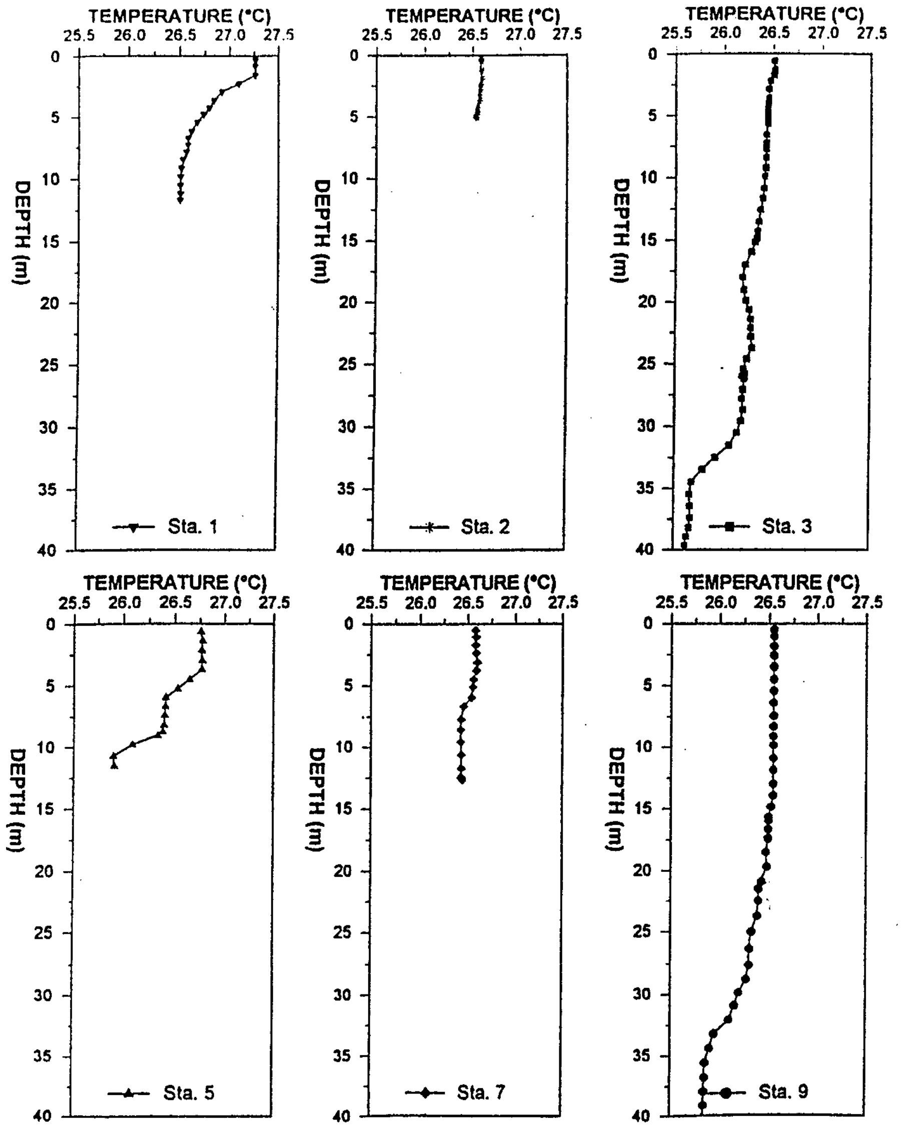


FIGURE 20. Vertical profiles of temperature measured at six inshore stations on July 14, 1995 near the Fort Kamehameha sewage outfall extension. For station locations, see Figure 1.

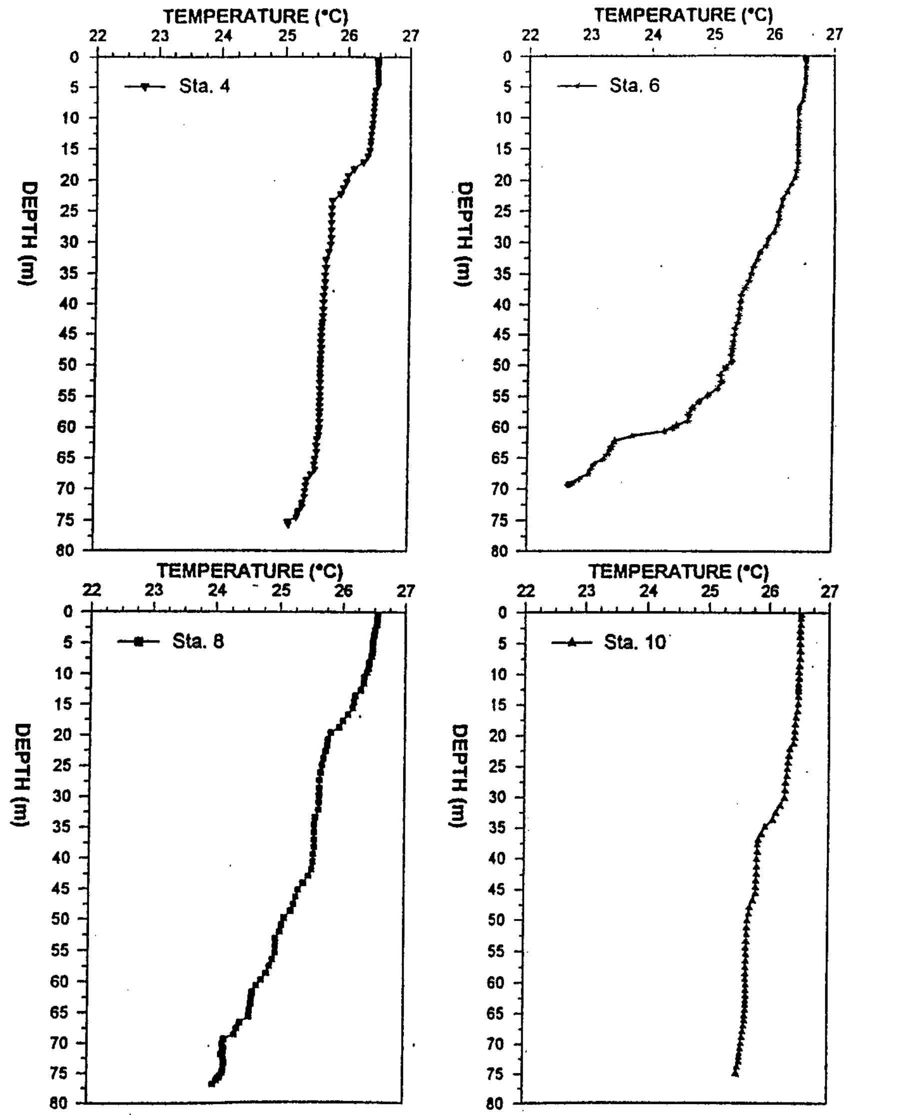


FIGURE 21. Vertical profiles of temperature measured at four offshore stations on July 14, 1995 near the Fort Kamehameha sewage outfall extension. For station locations, see Figure 1.

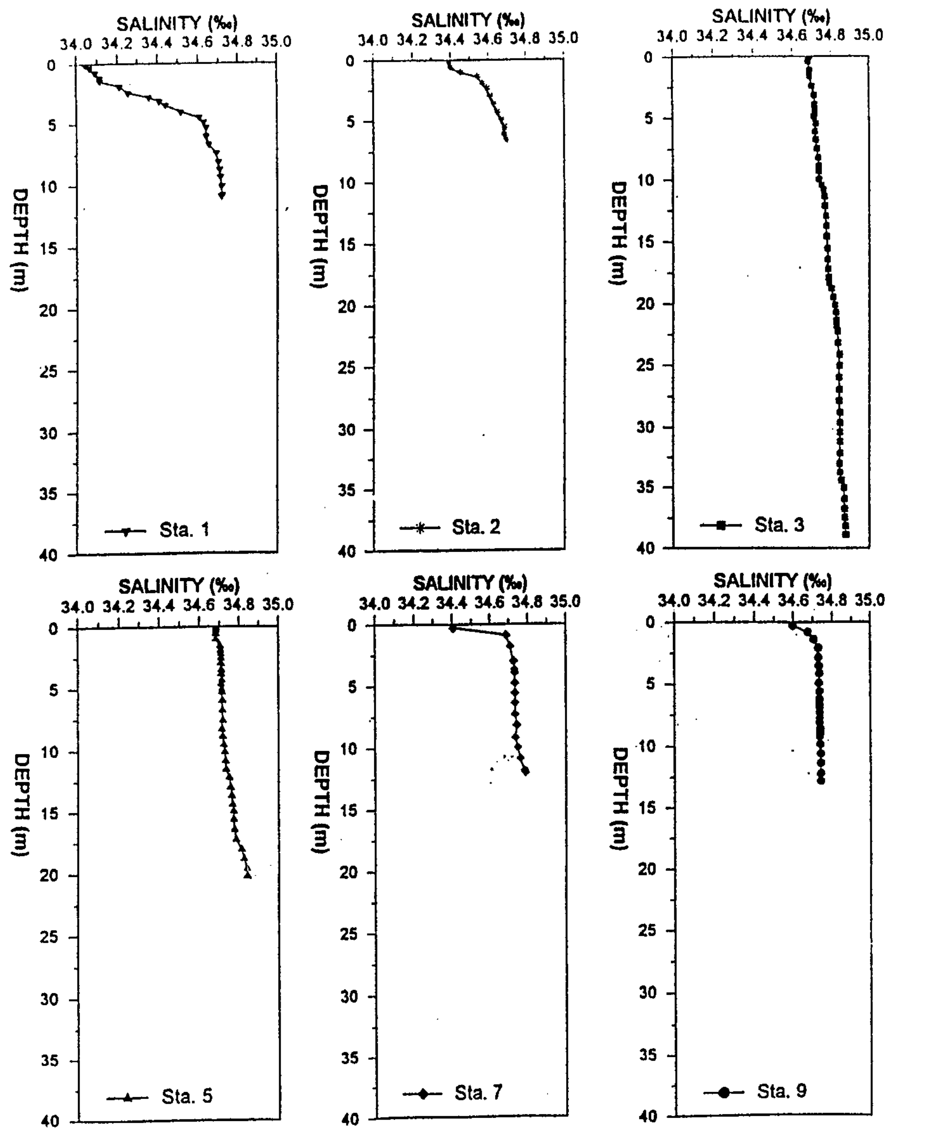


FIGURE 22. Vertical profiles of salinity measured at six inshore stations on September 14, 1995 near the Fort Kamehameha sewage outfall extension. For station locations, see Figure 1.

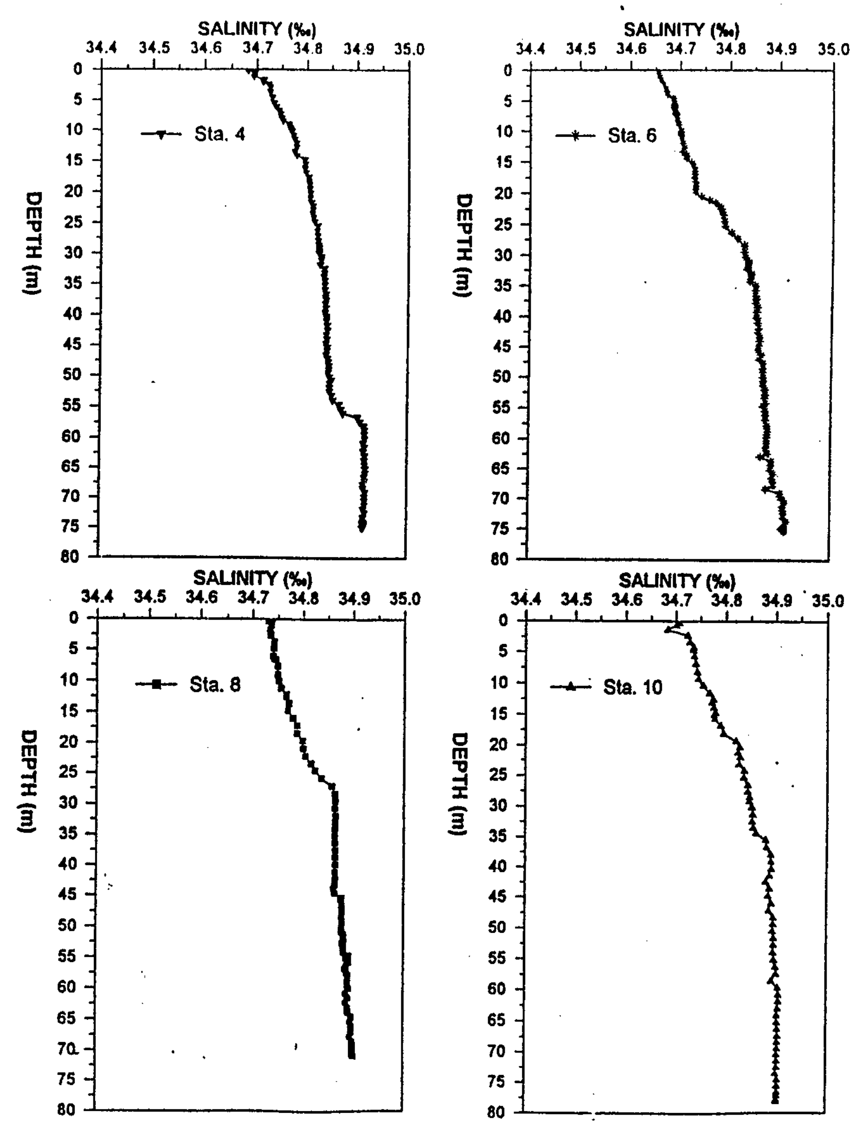


FIGURE 23. Vertical profiles of salinity measured at four offshore stations on September 14, 1995 near the Fort Kamehameha sewage outfall extension. For station locations, see Figure 1.

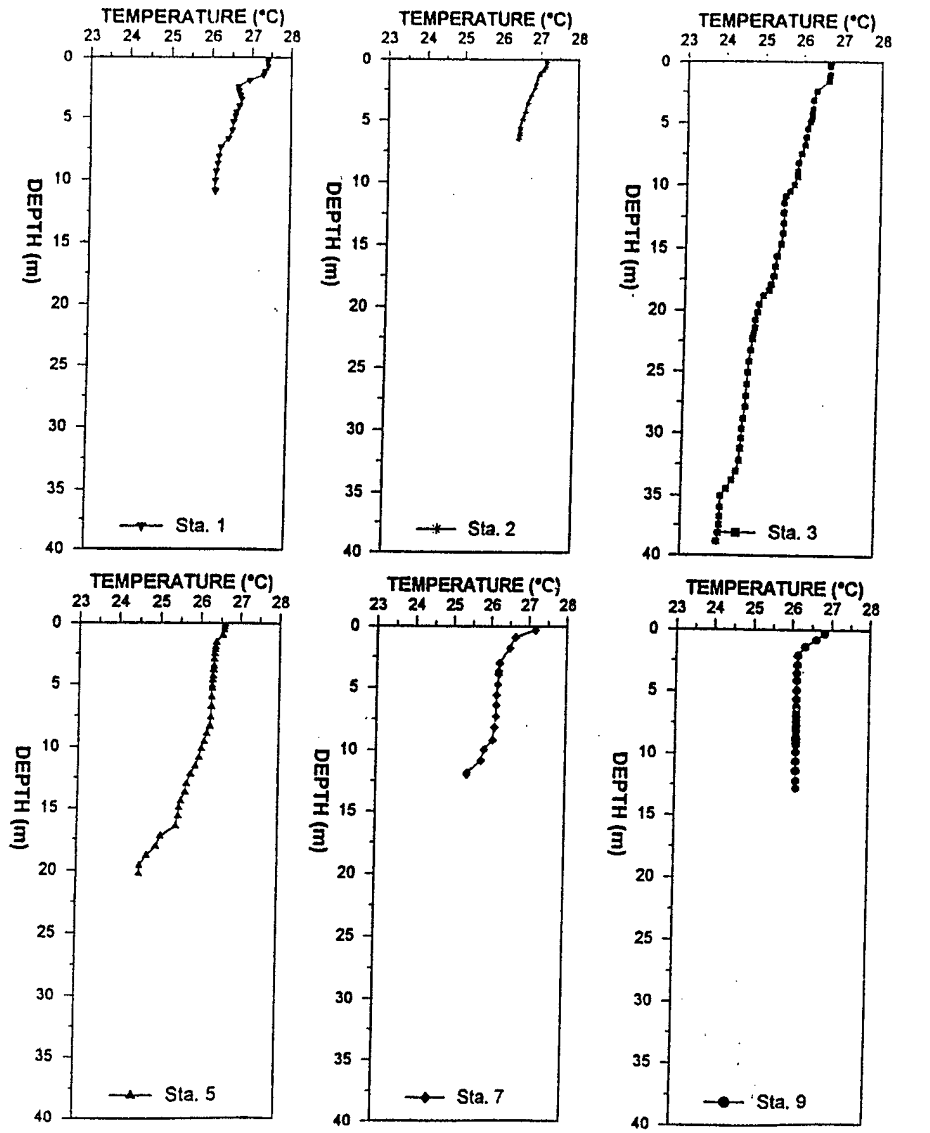


FIGURE 24. Vertical profiles of temperature measured at six inshore stations on September 14, 1995 near the F Kamehameha sewage outfall extension. For station locations, see Figure 1.

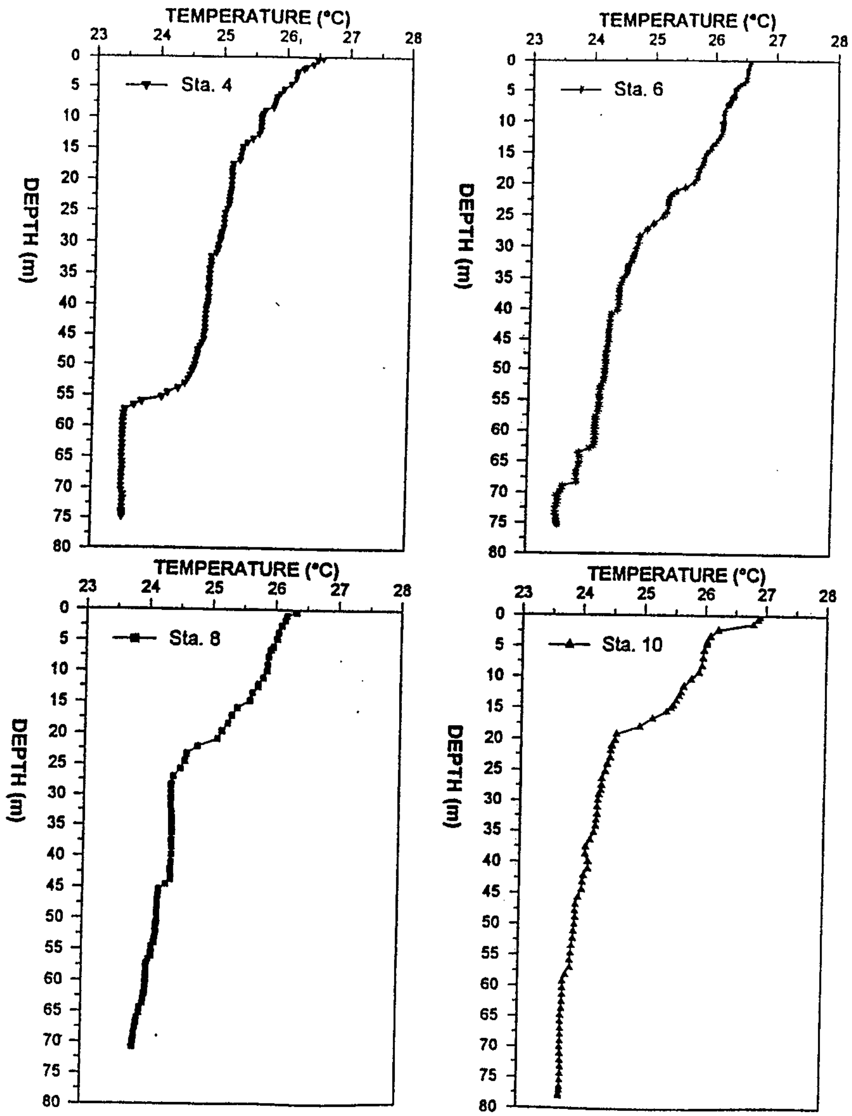


FIGURE 25. Vertical profiles of temperature measured at four offshore stations on September 14, 1995 near the Fort Kamehameha sewage outfall extension. For station locations, see Figure 1.

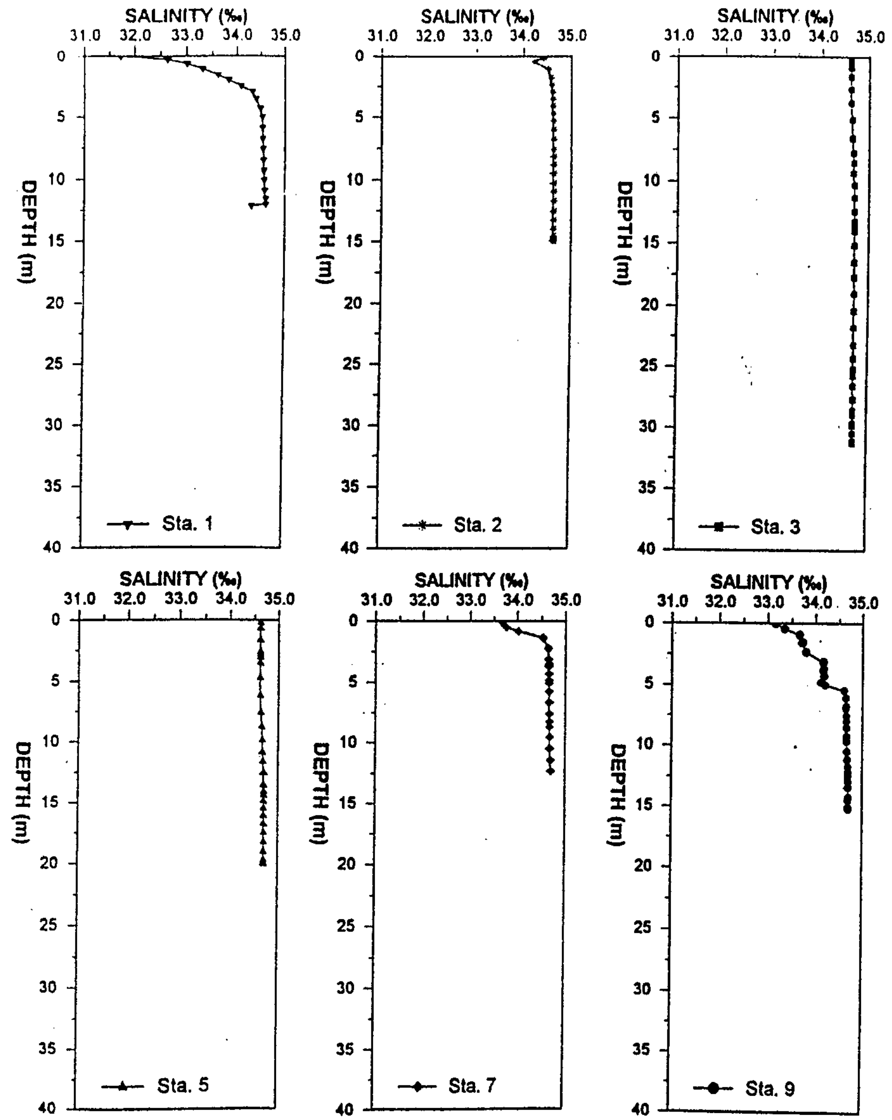


FIGURE 26. Vertical profiles of salinity measured at six inshore stations on November 7, 1995 near the Fort Kamehameha sewage outfall extension. For station locations, see Figure 1.

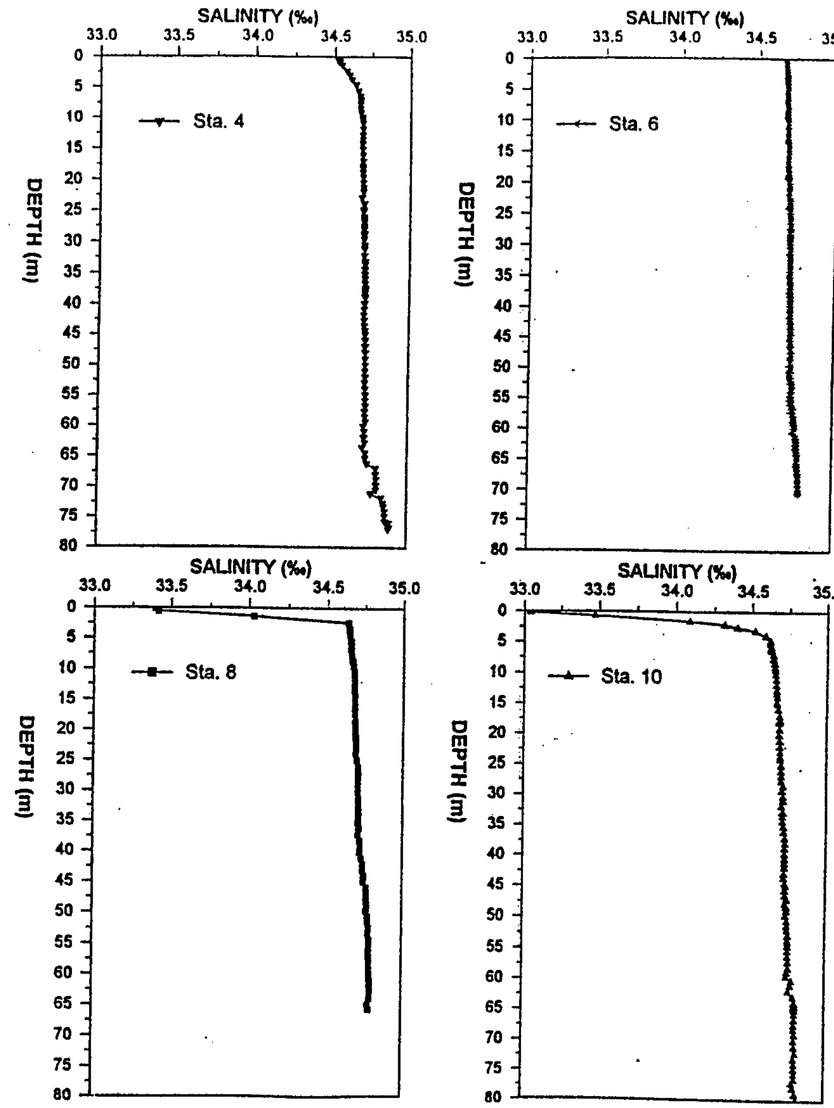


FIGURE 27. Vertical profiles of salinity measured at four offshore stations on November 7, 1995 near the Fort Kamehameha sewage outfall extension. For station locations, see Figure 1.

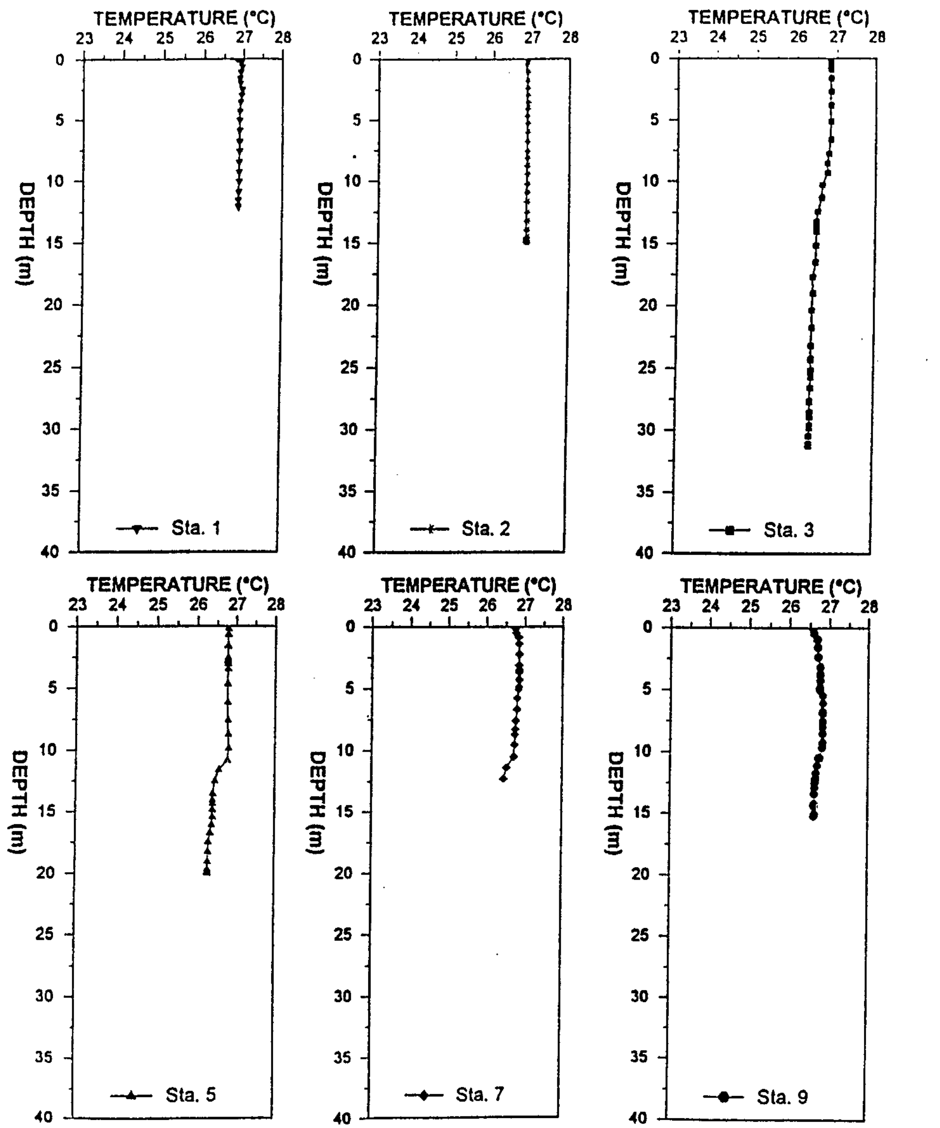


FIGURE 28. Vertical profiles of temperature measured at six inshore stations on November 7, 1995 near the Fort Kamehameha sewage outfall extension. For station locations, see Figure 1.

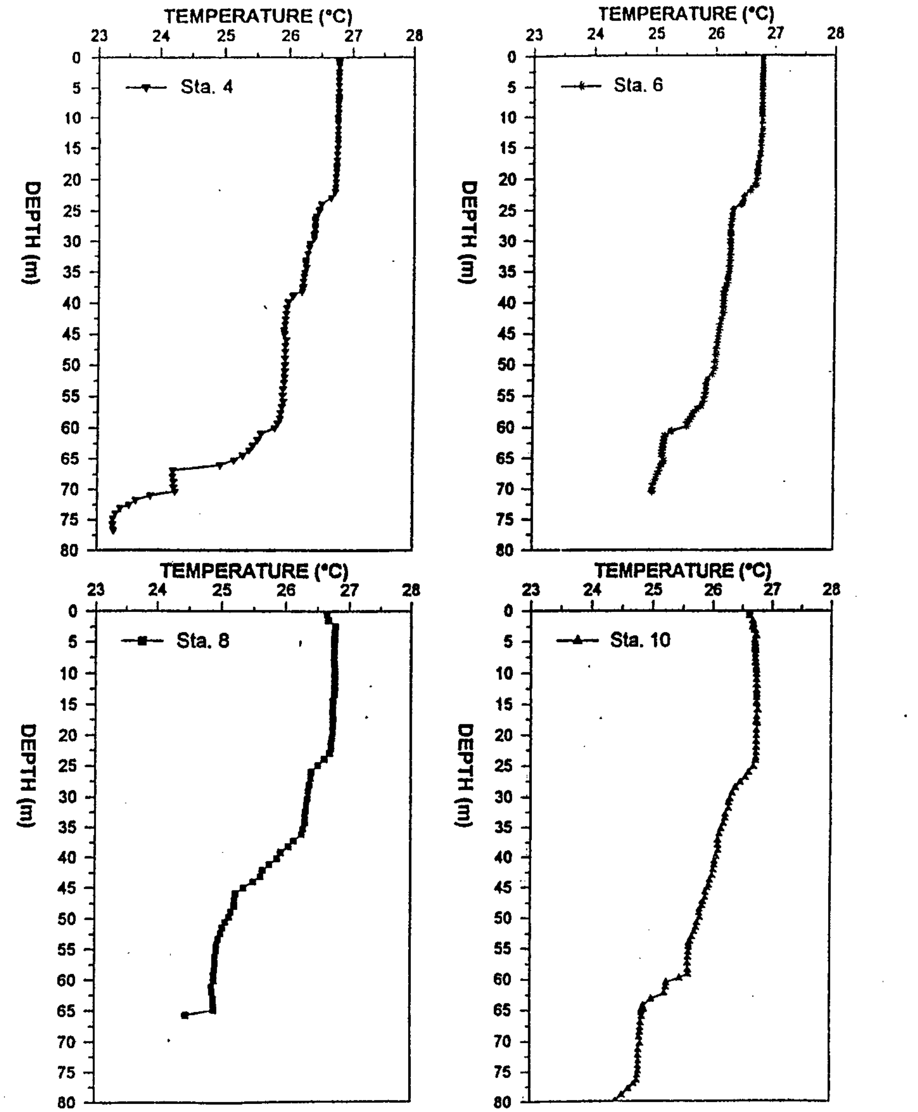


FIGURE 29. Vertical profiles of temperature measured at four offshore stations on November 7, 1995 near the Fort Kamehameha sewage outfall extension. For station locations, see Figure 1.

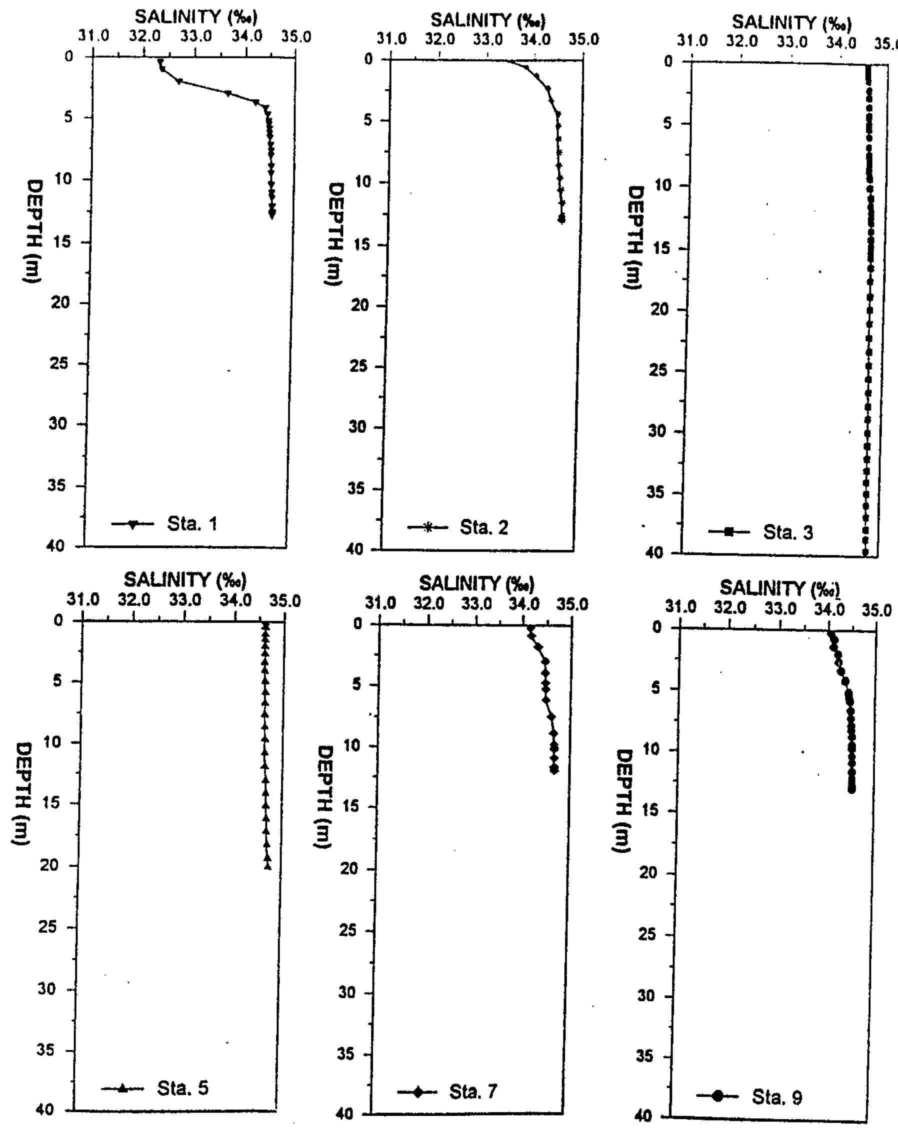


FIGURE 30. Vertical profiles of salinity measured at six inshore stations on January 6, 1996 near the Fort Kamehameha sewage outfall extension. Sampling was conducted one day after rains and flooding impacted the area. For station locations, see Figure 1.

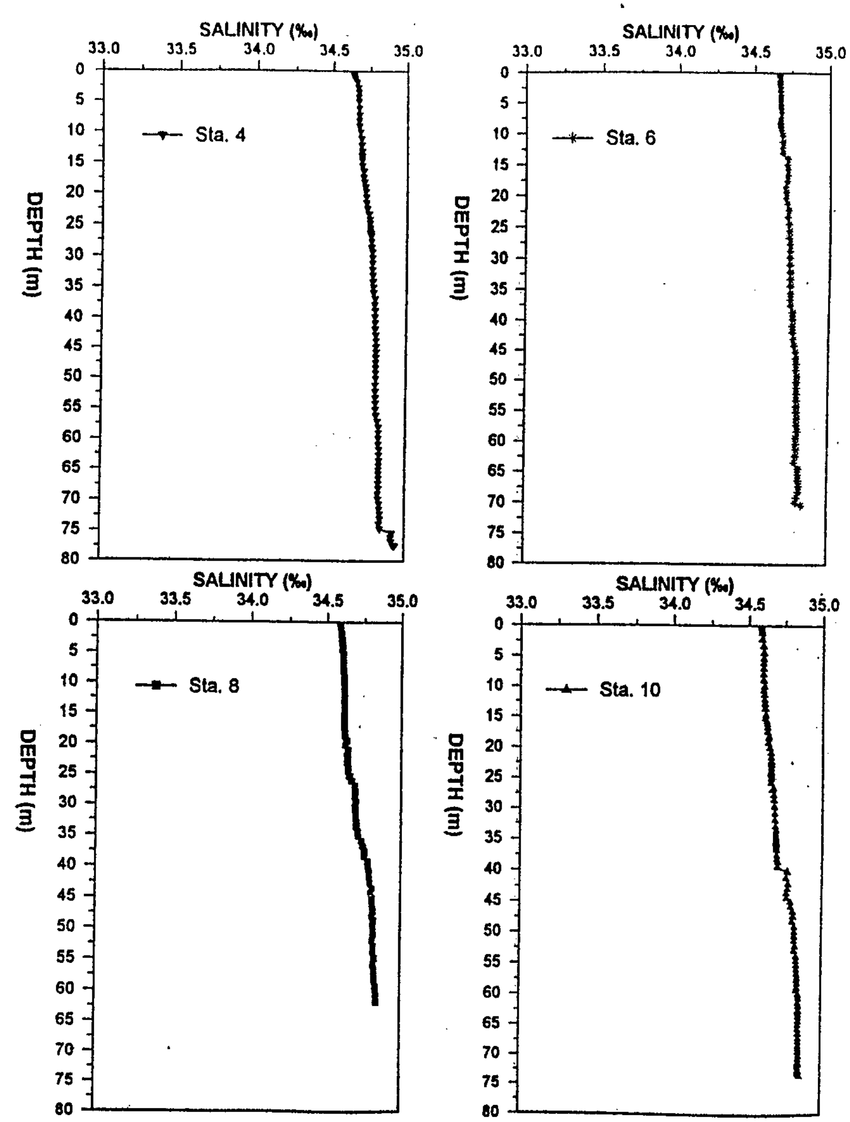


FIGURE 31. Vertical profiles of salinity measured at six offshore stations on January 6, 1996 near the Fort Kamehameha sewage outfall extension. Sampling was conducted one day after rains and flooding impacted the area. For station locations, see Figure 1.

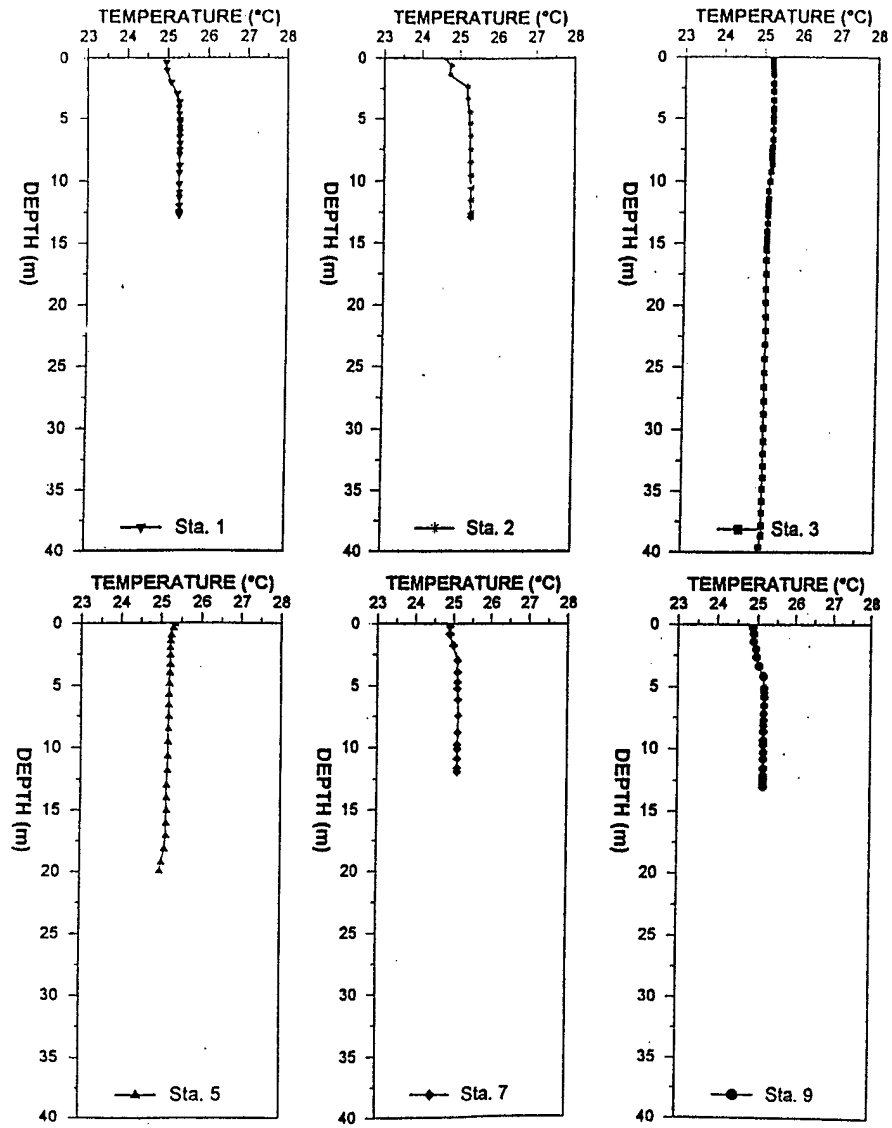


FIGURE 32. Vertical profiles of temperature measured at six inshore stations on January 6, 1996 near the Fort Kamehameha sewage outfall extension. Sampling was conducted one day after rains and flooding impacted the area. For station locations, see Figure 1.

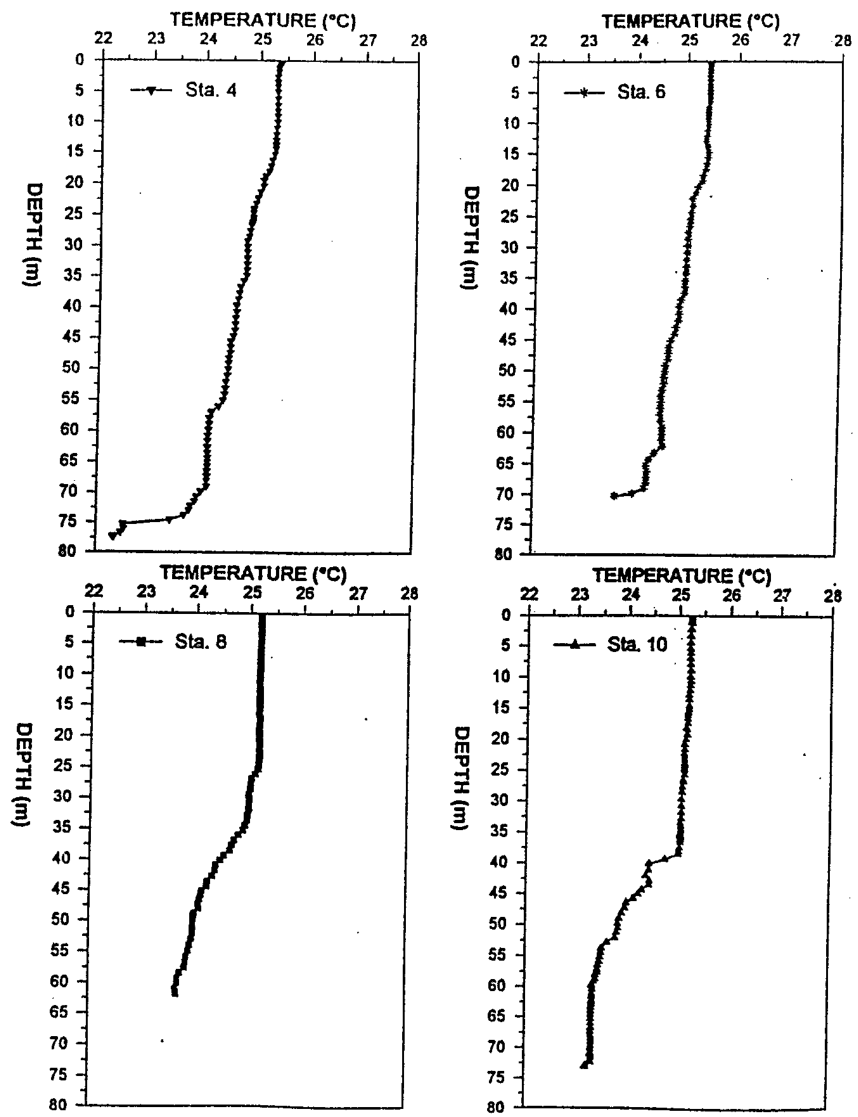


FIGURE 33. Vertical profiles of temperature measured at six offshore stations on January 6, 1996 near the Fort Kamehameha sewage outfall extension. Sampling was conducted one day after rains and flooding impacted the area. For station locations, see Figure 1.

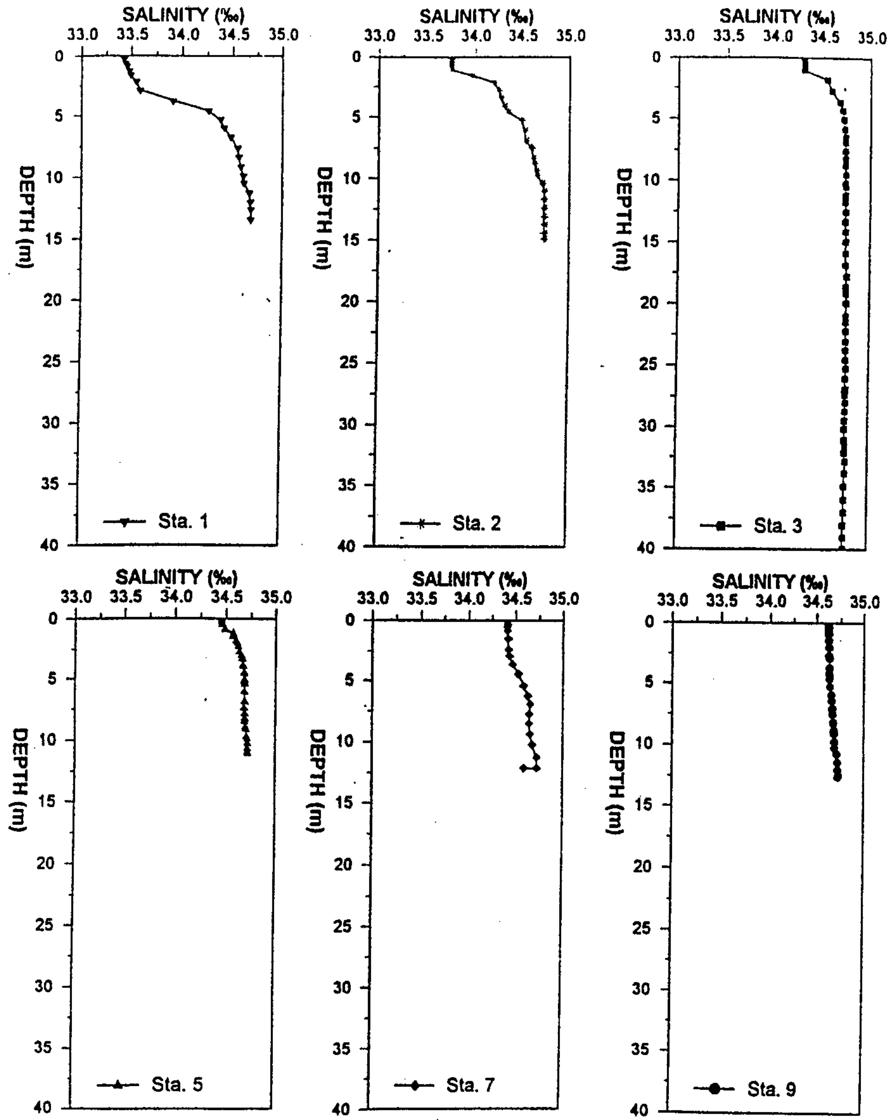


FIGURE 34. Vertical profiles of salinity measured at six inshore stations on February 7, 1996 near the Fort Kamehameha sewage outfall extension. For station locations, see Figure 1.

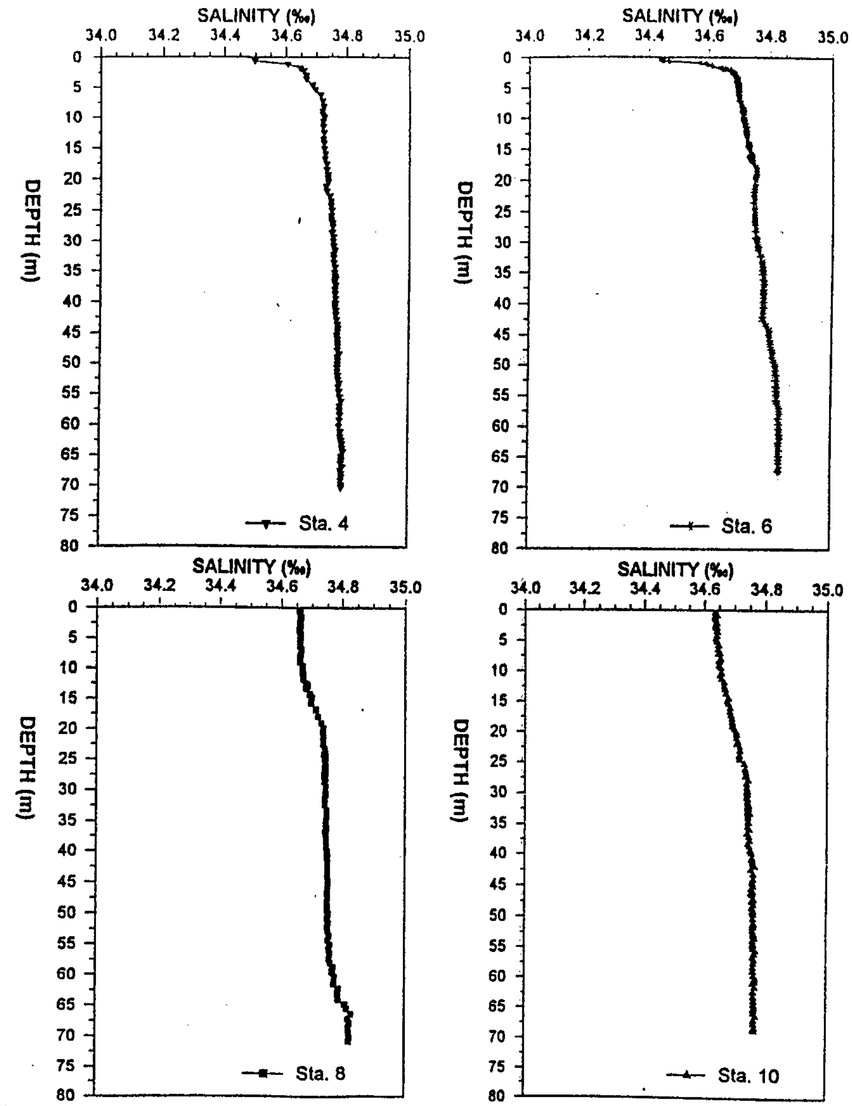


FIGURE 35. Vertical profiles of salinity measured at four offshore stations on February 7, 1996 near the Fort Kamehameha sewage outfall extension. For station locations, see Figure 1.

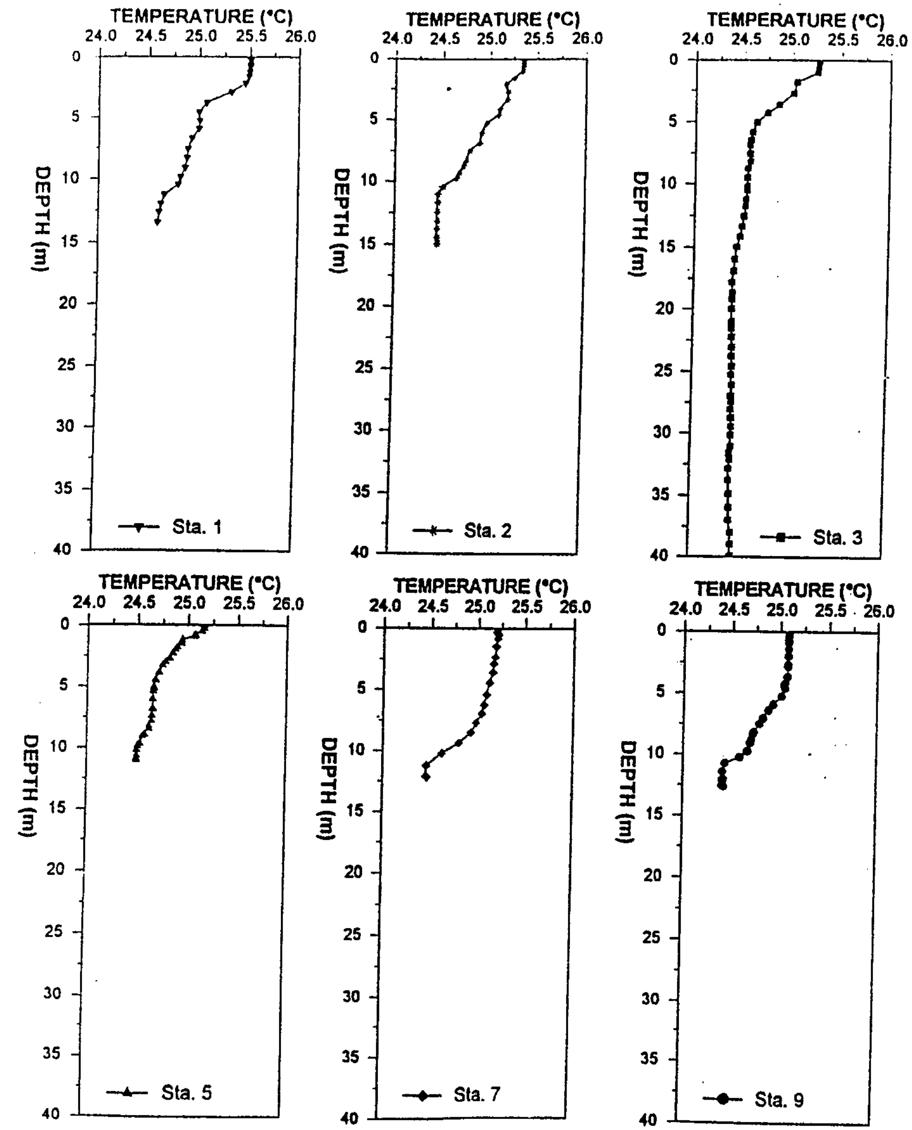


FIGURE 36. Vertical profiles of temperature measured at six inshore stations on February 7, 1996 near the Fort Kamehameha sewage outfall extension. For station locations, see Figure 1.

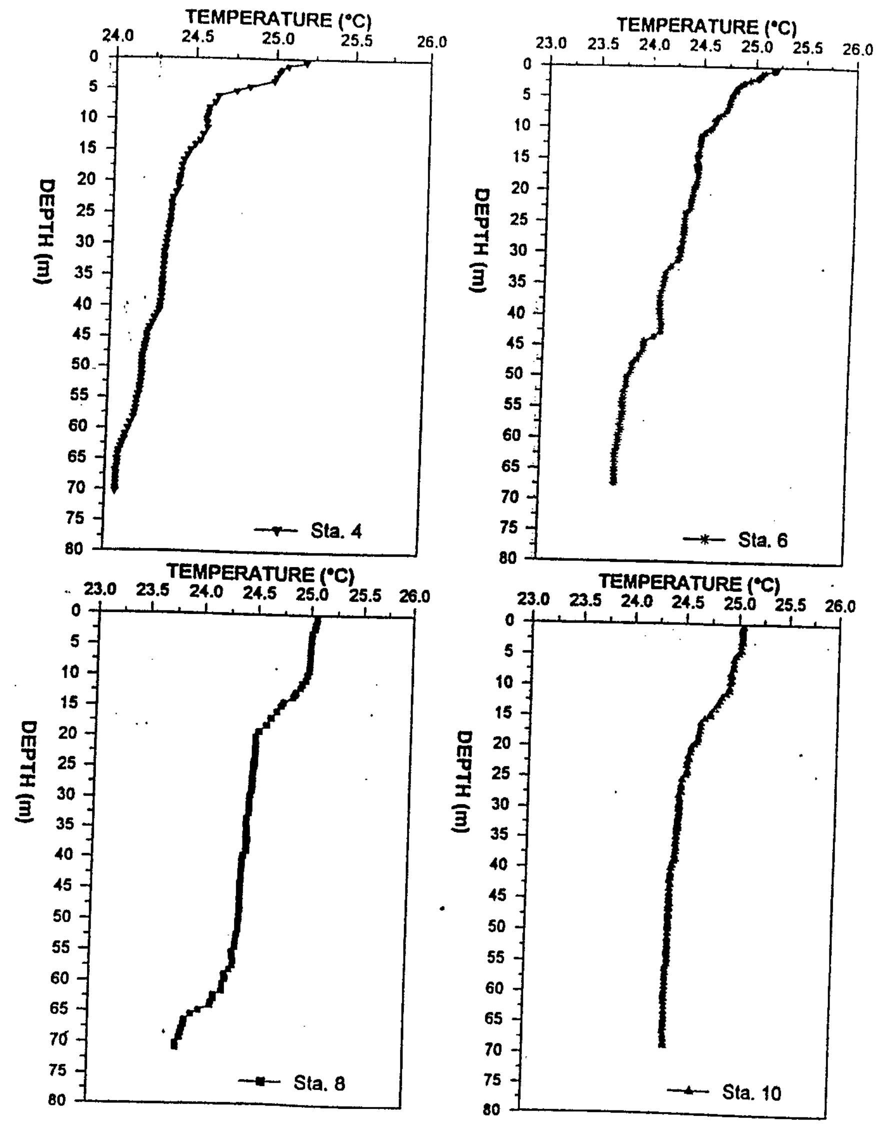


FIGURE 37. Vertical profiles of temperature measured at four offshore stations on February 7, 1996 near the Fort Kamehameha sewage outfall extension. For station locations, see Figure 1.

Appendix VII

An Assessment of Biological Communities in the Vicinity of the Proposed Fort Kamehameha Sewer Outfall

AN ASSESSMENT OF BIOLOGICAL COMMUNITIES IN THE VICINITY OF THE PROPOSED FORT KAMEHAMEHA SEWER OUTFALL

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EXECUTIVE SUMMARY

The expansion of the Fort Kamehameha Sewage Disposal Facility will involve construction of a new discharge pipe extending from the Treatment Plant to offshore waters of 45 meters (m) depth. In order to reach deep water, the new pipe will traverse a shallow reef flat that comprises the offshore area between the eastern edge of the Pearl Harbor entrance channel and the shoreline. Considerations in selecting the exact route, as well as selecting the method of pipe construction, are the effects on the existing biotic composition of the reef flat and offshore areas. The following report describes the biotic composition of the regions that will be affected by the pipeline installation and provides an evaluation of the potential impacts of the proposed construction.

Four biotopes (e.g. distinct habitats) were identified on the reef flat. These include: 1) Mangroves along the shoreline; 2) Reef Flat, consisting of shallow sand-covered limestone bench; 3) Reef Crest, consisting of the elevated margin of the reef flat adjacent to the harbor entrance channel, and; 4) Sand Cays which are two small islets in the middle of the reef flat. Seaward of the reef flat bottom contours deepen, and four distinct habitats were identified: Reef Slope, Rubble Zone, Limestone Bench, and Sand Flats.

Each of these habitats contains a varied assemblage of organisms including corals, other benthic invertebrates, fish, and benthic plants (algae). However, none of the organisms observed are particularly abundant, nor are they considered rare or endangered species. Most of the species assemblages are commonly found in other similar Hawaiian environments. It is clear that the existing biota in the path of the discharge pipe will be removed during the construction process. Thus, the route with the least abundant and diverse biota was a criteria in selecting the proposed pipeline route. Along the 1160 m long construction corridor from the shoreline to the Pearl Harbor channel floor, it is estimated that corals presently comprise about 0.06% of bottom cover.

During construction, it is likely that there will be increases in suspended sediment on the reef flat and surrounding areas. While reef organisms may be affected by such increases, it is not likely that such impacts will be severe for several reasons. Sediments are a natural component of the environment, and are frequently stirred into the water column by natural phenomena such as normal wave action as well as storms. The existing literature indicates that in Hawaiian environments, the effects from suspended sediment generated from construction projects are usually minor or non-existent.

Burial of the discharge pipe on the reef flat will result is essentially returning the habitat to the same condition that existed prior to construction. As a result, the areas should recolonize to a condition similar to which exists at present with no long term detrimental effects. Temporary removal of the portion of the habitat that comprises the pipeline route will entail only a very small percentage of the total reef flat (less than 1%); the remaining undisturbed areas should constitute a adequate area for all biotic processes to continue as they are at present.

It is possible that the existing biotic composition on the reef flat is influenced by nutrient enrichment from the existing Fort Kamehameha sewage discharge. Thus, because the proposed deep discharge has little chance of returning to shore, moving the point of discharge from shallow to deep water could affect the composition of the reef flat. This possibility appears very remote for several reasons. Observations of the reef flat reveal similar community assemblages from 1972 to the present, with no apparent progressive shifts in abundance with effluent discharge. In addition, the predominant direction of flow of water exiting the Pearl Harbor channel is to the west, away from the reef flat. Thus, only in relatively uncommon Kona conditions would effluent move over the reef flat. In any event, it is generally considered a negative impact to change biotic composition in response to sewage discharge. Thus, removing sewage discharge that cause such changes cannot be viewed as an environmental detriment.

INTRODUCTION AND PURPOSE

A. PROJECT DESCRIPTION

The Waste Water Treatment Plant (WWTP) at Fort Kamehameha was constructed in 1968 and treats domestic and industrial wastewater from the Pearl Harbor Naval Base, Hickam Air Force Base, and Hickam Village. The treatment plant is operated by the U.S. Navy. The effluent is presently discharged through a reinforced concrete pipe 549 meters (m) long, and 76 centimeters (cm) in diameter that runs along the east side of the Pearl Harbor entrance channel. The pipe terminates in a multi-port diffuser at the eastern edge of the entrance channel at a depth of 13.7 m. The receiving waters at the existing discharge site are regulated as a Class 2 inland estuary under current State of Hawaii Department of Health regulations.

The WWTP at Fort Kamehameha is presently being expanded to meet higher projected flows. The present flow is approximately 7.5 million gallons per day (MGD), while the projected average, maximum and peak flows are 13, 20 and 30 MGD, respectively. State regulations are very restrictive and stipulate that "no new industrial or sewage discharges will be permitted within estuaries". Thus, extending the outfall to discharge effluent into Class A "wet" open coastal waters will allow the projected increased flows to be discharged in compliance with existing regulatory requirements.

Present plans for the outfall extension involve placing the discharge pipe in a trench extending from the Treatment Plant across approximately 1100 m of reef flat that extends along the eastern boundary of the Pearl Harbor entrance channel. At the edge of the reef flat the pipe will drop into the entrance channel and extend approximately 2440 m across the channel floor to a depth of 46 m. A 200 m long multiport diffuser will extend in a southeasterly direction along the 46 m depth contour.

As part of the environmental documentation required to support the proposed project, studies were conducted to assess the marine ecosystems in the vicinity of the proposed outfall and diffuser locations. A study completed in 1996 evaluated water chemistry in the area of the probable Zone of Mixing (ZOM) of the extended outfall, and qualitative descriptions of the marine biotic community structure in the area of the probable outfall routes (Marine Research Consultants 1996). These surveys provided the baseline

of background conditions, as well as a basis for evaluation of possible environmental consequences of the proposed project within the ZOM. For preparation of the Environmental Impact Statement, further marine environmental investigations were warranted. The present report is an evaluation of biotic communities within the proposed placement area for the new outfall pipe structure.

METHODS

The proposed pipeline will cross a large reef flat that lies on the eastern side of the Pearl Harbor entrance channel between the location of the existing treatment plant and Hickam Harbor. Much of this reef flat is quite shallow, with less than 1 m of water over most of the flat at low tides. In this region, marine communities across this reef flat as well as in the path of two proposed alignments were examined by a combination of wading and snorkeling. Where water depth was greater i.e., seaward of the reef, SCUBA gear was used. An important criterion in this study was to broadly examine marine communities over the entire area with the purpose of determining possible routes that would cause the least amount of disturbance to these communities. This concept is predicated on the hypothesis that pipeline routes through more biologically depauperate areas will result in less potential impact than would routes through more populated areas.

The primary methods used in this study were (1) a delineation of major biotopes or zones in the study area and (2) a simple inventory of diurnally exposed marine species and noting their relative abundance in each biotope. Biotopes are defined by physical, geological and biological characteristics of an area. Physical characteristics which delineate biotopes include water depth, relative exposure to wave and current action. Geological features include the major structural components such as the amount of sand, hard substratum, and vertical relief. Biological attributes include relative coral coverage, fish abundance, and dominant species in the benthic community. Biotopes were named for distinctive features of each as shown in Figure 1.

Qualitative/semi-quantitative inventories were made in each biotope by noting the relative abundance of all species seen. Emphasis was placed on the diurnally-exposed benthic and motile fauna and flora that are at least 2 cm in some dimension. Thus, small sand-dwelling cryptic invertebrate species were not noted unless their presence could be determined without disturbing the substratum.

RESULTS

As presently planned, the proposed pipeline alignment will cross the reef flat that lies on the east side of the Pearl Harbor entrance channel. This reef flat encompasses approximately 69.6 ha or 172 acres. Four biotopes were recognized on this reef flat including the biotope of mangroves, the reef flat biotope, the biotope of sandy cays and the reef crest biotope. The approximate physical extent of each of these biotopes is given in Figure 1. It should be noted that the boundaries of each zone are not sharp but rather grade from one to another; these are ecotones or zones of transition. The results are presented by biotope and these are divided between the zones found on the shallow reef flat from those located in areas seaward of the reef flat.

I. Biotopes of the Fort Kam Reef

A. Biotope of Mangroves

The biotope of mangroves is so named for the introduced mangrove tree (*Rhizophora mangle*). Mangroves occur along the shoreline in two locations in the study area; one area adjacent to the WWTP on the west (as part of an old pier) and to the east along the shoreline east of the officer's quarters in the vicinity of what was the mouth of an intermittent stream before the development of this area by the military in the early 1900's (see Figure 1). This biotope occurs in the intertidal region and thus much of the substratum is exposed at low tides. The substratum around the mangroves is comprised of sand, fine mud and coral rubble; along the western thicket, some basalt rock is present probably from the construction of the old adjacent pier.

Inspection of the hard substratum in this biotope resulted in a relatively short list of common benthic species including the sponges (*Microciona maunaloa, Halichondria coerulea*, and *Tethya* sp.), algae (*Acanthophora spicifera, Dictyosphaeria versluysii*), anthozoan (*Zoanthus pacificus*), oysters (*Isognomon californicum, I. Pena, Ostrea sandvicensis*), molluscs (*Vermetus alii, Crepidula aculeata, Hipponix* spp.), and polychaetes (*Eurythoe complanata, Sabellastarte sanctijosephi, Pomatoleios kraussi*, and unidentified spioribids). Also present on a few of the subtidal rocks was the coral, *Leptastrea purpurea.* Coral cover in this biotope is very sporadic, and the small colonies present constitute less than 1% of bottom cover. Between the rocks, on the sand and mud, were the holothurian or sea cucumber *Opheodesoma spectabilis*, the brown crab (*Thalamita edwardsi*), the blue-pincher crab (*T. crenata*), unidentified snapping shrimp (probably *Alpheus crassimanus*), and several fish species including tilapia (*Tilapia*

melanopleura), juvenile aholehole (*Kuhlia sandvicensis*), the eleotrid (*Asterropteryx semipunctatus*), kaku (*Sphyraena barracuda*) and o'opu or goby (*Bathygobius fuscus*).

There were a number of the above benthic species on the emergent rock and mangrove prop roots as well as the littorine snail (*Littorina scabra*), black snail (*Nerita picea*), black crab (*Metopograpsus messor*), false limpet (*Siphonaria normalis*) and barnacles (dominant species *Balanus amphitrite amphitrite*).

B. The Reef Flat Biotope

The largest biotope present on the Fort Kam reef flat is the reef flat biotope. This biotope extends from the shoreline seaward to the crest of the old fringing reef more than 370 m offshore (reef crest biotope). The reef flat occupies more than 85% of the subtidal environment shoreward of the reef crest. Water depths (at mean tide) range from emergent substratum to approximately 1 m; the overall mean depth through this biotope is about 0.5 m. The substratum of this biotope is a mix of sand, rubble and emergent hard substratum. In general the underlying substratum is an old coralline/limestone bench with shallow deposits of sand and coralline rubble overlying it. Through most of this biotope, the dominant benthic species is the introduced alga, *Acanthophora spicifera*. Where this biotope exists in more wave-protected waters such as directly adjacent to shore, the dominant benthic species are a mix of limus *Acanthophora spicifera* and *Gracilaria salicornia*. On O'ahu, *Gracilaria salicornia* has been commonly reported only from Kaneohe Bay and Waikiki but is apparently known from a number of localities on the outside islands (Dr. C. Smith, pers. comm.).

Other common benthic species seen on the reef flat include the anthozoan, *Zoanthus pacificus* which may reach local coverage of up to 80% in isolated patches of 5 to 20 square meters in size. Other observed algal or limu species of considerably lesser coverage included ogo (*Gracilaria bursapastoris*), limu manauea (*Gracilaria coronopifolia*), *Caulerpa sertularioides*, *Chlorodesmis hildenbrandtii*, limu 'ele'ele (*Enteromorpha* sp.), *Microdictyon setchellianum*, *Lyngbya majuscula*, limu alani (*Dictyota bartayresii* and *D. sandvicensis*), *Dictyosphaeria cavernosa* and *D. versluysii*, *Padina* spp., limu kala (*Sargassum polyphyllum*), *Hypnea* spp., limu mane'one'o (*Laurencia nidifica*), *Spyridia filamentosa* and *Tolypiocladia* spp. As noted above, the dominant benthic algal species are *Acanthophora spicifera*, *Gracilaria salicornia* as well as *Spyridia filamentosa* and *Hypnea* spp. Sessile benthic invertebrates seen in this biotope include sponges (*Halichondria coerulea*, *Tedania ignis*, *Mycale cecilia*, and *Terpios granulosa*), polychaetes (*Sabellastarte sanctijosephi*, *Chaetoperus* spp., as well as dextral and sinistral spirobids),

the hydrozoan (*Halocordyle disticha*), bryozoans (*Schizoporella unicornis*, *Bugula neritina*, *B. californica*), tunicates (*Ascidia interrupta*, *A. nigra*, *Polyclinum constellatum* and *Botrylloides nigrum*) and molluscs (*Ostrea sandvicensis*, *Vermetus alii*, *Crepidula aculeata*, *Isognomon californicum*, *I. Pena*, *Anomia* sp. and *Crucibulum spinosus*). Motile species seen here include the crabs (*Thalamita crenata*, *T. edwardsi*, and juvenile *Scylla serrata*), unidentified xanthid crabs (at least two species), mantis shrimp (*Gonodactylus falcatus*), burrowing shrimp (*Alpheus mackayi*), ghost shrimp (*Callianassa variabilis*), shrimp (*Saron marmoratus*), box crab (*Calappa hepatica*), spindle shell (*Peristernia chlorostoma*), clam (*Tellina rugosa*), black sea urchin (*Tripneustes gratilla*), green urchin (*Echinometra mathaei*), wana (*Echinothrix diadema*), banded urchin (*E. calamaris*), black sea cucumber (*Holothuria atra*), brown sea cucumber (*H. verrucosa*), olive-green sea cucumber (*Stichopus chloronotus*), and pink sea cucumber (*Opheodesoma spectabilis*). Insects are also present in this biotope including the water strider (*Halobates sericeus*).

Stony corals occurred in the reef flat biotope in two subzones. In the shallower, nearshore portions of the reef flat, corals were relatively rare and constituted a very small component of bottom cover (far less than 1%). Coral species that were observed included *Pocillopora damicornis*, *Porites compressa*, and *Porites lobata*. Most of these corals were small colonies growing on large rubble fragments. In the outer regions of the reef flat (shoreward of the reef crest) water depth increases to approximately 1 meter. In this area, large (up to 2 m) in diameter colonies of *Porites compressa* occur. In some instances, these colonies are circular in shape with hollowed out non-living centers surrounded by outward growing edges. Such "microatolls" are a common growth form for many corals on shallow reef flats where the upward limit of growth is determined by the shallow water depth. In localized area of up to 50 m^2 these large colonies comprise 15-20% of bottom cover. Throughout the entire outer reef flat biotope, coral cover is estimated at 5-10% of bottom cover.

Fishes are occasionally seen in the reef flat biotope. Probably the most visible are puffers because of their relatively slow swimming habits. Puffer species seen include the smooth puffer or keke (*Arothron hispidus*), spiny puffers kokala (*Diodon hystrix*) and 'o'opu okala (*Diodon holocanthus*). Other fish species seen include tilapia (*Tilapia melanopleura*), the belted wrasse or 'omaka (*Stethojulis balteata*), the saddleback wrasse or hinalea lauwili (*Thalasoma duperrey*), lizard fish or 'ulae (*Synodus variegatus*), eleotrid (*Asterropteryx semipunctatus*), o'opu or goby (*Bathygobius fuscus*), flatfish or paki'i (*Bothus mancus*), moray eel or puhi laumilo (*Gymnothorax undulatus*), and boxfish or moa (*Ostracion meleagris*). Baitfishes are occasionally seen on the reef flat including the silverside or 'iao (*Pranesus insularum*), nehu (*Stolephorus purpureus*) and gold spot

herring (*Herklotsichthys quadrimaculatus*). There are a number of other fish species found in the reef flat biotope that are usually more difficult to see because of their wariness. This group includes species that have recreational, subsistence and commercial importance. Among these species are the introduced mullet (*Chelon engli*), yellowstripe goatfish or weke (*Mulloides flavolineatus*), nightmare goatfish or weke pueo (*Upeneus arge*), barracuda or kaku (*Sphyraena barracuda*), the flagtail or aholehole (*Kuhlia sandvicensis*), mullet or ama'ama (*Mugil cephalus*), mullet or uouoa (*Neomyxus leuciscus*), milkfish or 'awa (*Chanos chanos*), bonefish or oi'o (*Albula vulpes*), leatherback or la'i (*Scomberoides lysan*), and several jack species or papio (*Caranx melampygus, C. ignobilis, C. sexfasciatus, Carangoides orthogrammus*). Many of these species are seen on the reef flat during periods of high tide when they will move into these shallow waters from more offshore deeper areas to feed but, in general, are more commonly encountered and fished for in the deeper waters just seaward of the reef flat and crest habitats.

The sand substratum of the reef flat biotope is home to a number of species that burrow and other than the obvious entrances to their burrows, remain hidden from view. Among this group are a number of crustaceans (primarily shrimps), polychaete worms, hemicordates (such as *Ptychodera flava*) and holothurians. No attempt was made to identify these for none are diurnally visible.

C. The Reef Crest Biotope

The reef crest biotope occurs just seaward of the reef flat biotope. The reef crest separates the reef flat from the entrance channel and the reef slope. As the name implies, water depth in the reef crest biotope can be less than found on the reef flat, and at low tidal stands, parts of the reef crest can be emergent. This biotope is quite narrow with widths ranging between 15 to 30 m and the long axis of the biotope approximately paralleling the shoreline (see Figure 1). The substratum of this biotope is primarily limestone, much of which may be exposed to the air at low tides. In some areas coral rubble covers much of the hard substratum. Dominant species seen over much of the reef crest biotope include the crustose coralline algae (*Porolithon onkodes, P. gardineri*, and *Peyssonellia rubra*), the red alga *Acanthophora spicifera*, green alga *Dictyosphaeria cavernosa*, and brown alga *Turbinaria ornata*. Sea urchins are common in this biotope and species seen include the wana (*Echinothrix diadema*), the banded urchin (*E. calamaris*), black boring urchin (*Echinometra oblongata*), green urchin (*E. mathaei*), and black urchin (*Tripneustes gratilla*). Both the white-spot brown sea cucumber (*Actinopyge mauritiana*) and the black sea cucumber (*Holothuria atra*) are

present in this biotope as are the mantis shrimp (*Gonodactylus falcatus*), ghost shrimp (*Callianassa variabilis*), and green shrimp (*Saron marmoratus*). Because much of this biotope is quite shallow or is exposed to the air at low tides, only a few fishes were seen but most of them must cross the reef crest and reef flat biotopes in their daily foraging movements.

Perhaps the most interesting aspect of the reef crest biotope are the abundance and diversity of corals. Corals are not found through the entire length of the biotope but are more prevalent along the eastern third of the area. As discussed above, abundant corals are first seen in the transition zone between the reef flat biotope and the reef crest biotope. In the reef crest biotope the most abundant coral species (in terms of coverage) is *Porites compressa* with local coverage up to 20 percent (in areas from 2 to 10 square meters). Other coral species present include *Porites lobata, Pavona varians, Pocillopora meandrina, P. damicornis, Leptastrea purpurea* and the anthozoans *Zoanthus pacificus* and *Palythoa tuberculosa*. While there area areas of locally abundant coral, overall coral coverage throughout the biotope is less than 5 percent.

D. The Sand Cay Biotope

The sand cay biotope is associated with two small sandy islets located between 50 to 80m offshore of the beach in the middle of the reef flat biotope (see Figure 1). This biotope is characterized by a sand and coralline rubble substratum but it is best developed were the sand has a finer grain size. This biotope provides little cover or hard substratum so the majority of the species seen are those that are usually found in sand habitats. On the beach of the islets are ghost crabs (*Ocypode ceratophthalma*); subtidally are numerous burrows made by crustaceans, polychaetes, hemichordates and holothurians of unknown indentity. Burrowing crustaceans include several species of alpheid and callianassid shrimps; among the most obvious burrowing polychaete species are the egg masses of *Arenicola brasiliensis* which protude above the sand (Bailey-Brock 1983) and the hemichordate (*Ptychodera flava*) is also known to be present. Motile species seen in this biotope include the mantis shrimp (*Gonodactylus falcatus*), the box crab (*Calappa hepatica*), the flatfish or paki'i (*Bothus mancus*) and the lizard fish or 'ulae (*Synodus variegatus*). Where there is more rubble substratum, the alga, *Acanthophora spicifera* is common as are the anthozoan (*Zoanthus pacificus*) and vermetid mollusc (*Dendropoma* sp.) on the upper surfaces of the rubble.

The burrowing polychaete *Arenicola brasiliensis* has a restricted known distribution around O'ahu; it has been reported from Kaneohe Bay and two restricted localities in

Moanalua Bay (Bailey-Brock 1984). This study increases the known distribution to include a small area on the Fort Kam reef flat (in the biotope of sandy cays).

2. Biotopes Seaward of the Fort Kamehameha Reef

The present study was confined to an area bounded by the Pearl Harbor entrance channel on the south and west and the Hickam small boat harbor entrance channel on the east. In this area three biotopes or zones were recognized; these are the reef slope, the rubble zone and the biotope of limestone and corals. The approximate distribution of these three biotopes are shown in Figure 2. Much of the reef slope biotope is also shown in Figure 1. The characteristics of each biotope are given below.

A. Reef Slope Biotope

Seaward of the reef crest biotope is the reef slope biotope which parallels the reef crest through the entrie study area. Along the western two-thirds of the study area, the reef slope biotope abruptly terminates at the edge of the dredged Pearl Harbor entrance channel. Over much of this area the biotope is no more than 20m in width. East of this, the reef slope biotope is broader and grades into the rubble biotope in a seaward direction (see Figure 2). The substratum of reef slope biotope is a mix of coralline rubble with patches of emergent limestone substratum some of which is covered by old dead coral growth. These features provide a small scale "spur and groove" zone which is characteristic of the seaward sides of many fringing reefs. The scale of the "spurs" ranges from about 1 to 4 m in width, and no more than 7 m in length; most are considerably smaller. The elevation of these ridges is between 0.4 to 0.8 m. The depressions or "grooves" between these elevated ridges range from 0.5 to 4 m in width and are up to 10 m in length often coalescing along their seaward sides. The substratum of these channels is primarily rubble.

East of the Pearl Harbor entrance channel this biotope expands seaward for about 80m; in this expanded area the "spurs" become less well defined being small areas of elevated limestone with some live coral growth. The most abundant coral in this area is *Porites lobata* and coverage is less than 5%. The elevated limestone "patches" are from 1 x 1 m in dimension to about 2 x 5 m and rise no more than 1.2 m from the otherwise rubble substratum. Water depth in the eastern part of the reef slope biotope ranges from 60 cm to about 3 m.

There is considerable variation in the degree of development of the marine communities in the reef slope biotope. In general, communities are more depauperate in a west direction (towards the inner harbor) and have a greater diversity of species in an eastern direction. However, the distribution of species is quite "patchy" through this biotope resulting in considerable local variation. This variation may be best described by providing two examples as given below.

Where biological diversity is high in the reef slope biotope, one encounters a number of coral species; the dominant corals are *Porites compressa, P. lobata* and *Pocillopora meandrina*. Other common species include *Pavona varians, Montipora verrucosa, M. patula, Pocillopora damicornis* and *Leptastrea purpurea*. Over small areas (between 2 to 15 square meters) coral coverage may range up to 25% but overall mean coverage is less than 1 percent. Common algal species include *Acanthophora spicifera* and *Porolithon onkodes*; benthic invertebrates include sea urchins (*Echinothrix diadema, E. calamaris, Echinometra mathaei, E. oblongata, Heterocentrotus mammillatus, Diadema setosum*, and *Tripneustes gratilla*), sea cucumbers (*Holothuria atra* and *Asteropyge mauritiana*), polychaete worms (*Sabellastarte sanctijosephi* and *Loimia medusa*), anthozoans (*Zoanthus pacificus* and *Palythoa tuberculosa*), hydrozoan (*Halocordyle disticha*), cone shells (*Conus lividus* and *C. miles*), black sea cucumber (*Holothuria atra*) and slipper lobsters or ula'papa (*Paribaccus antiarctus*). Also encountered in this biotope was a small school of squids or muhe'e (probably *Seploteuthis arctipinnis*).

Resident fishes include the brown surgeonfish or ma'i'i'i (*Acanthurus nigrofuscus*), convict tang or manini (*Acanthurus triostegus*), ringtail surgeonfish or pualu (*Acanthurus blochii*), goldring surgeonfish or kole (*Ctenochaetus strigosus*), yellowfin surgeonfish or palani (*Acanthurus dussumieri*), yellow tang or lau'ipala (*Zebrasoma flavescens*), saddleback wrasse or hinalea lauwili (*Thalassoma duperrey*), bird wrasse or hinalea i'iwi (*Gomphosus varius*), cleaner wrasse (*Labroides phthirophagus*), belted wrasse or 'omaka (*Stethojulis balteata*), smooth puffer or keke (*Arothron hispidus*), bulletnose parrotfish or uhu (*Scarus sordidus*), raccoon butterfly fish or kikakapu (*Chaetodon lunula*), tear drop butterfly fish or lau-hau (*Chaetodon unimaculatus*), damselfish or alo'ilo'i (*Dascyllus albisella*), damselfish (*Plectroglyphidodon johnstonianus*), sargeant major or mamo (*Abudefduf abdominalis*), trumpet fish or nunu (*Aulostomus chinensis*), manybar goatfish or moano (*Parupeneus multifasciatus*), yellowstripe goatfish or weke (*Mulloides flavolineatus*), moorish idol or kihikihi (*Zanclus cornutus*), and sharpback puffer (*Canthigaster jactator*). Besides these resident species other more migratory commercially important species as noted on the reef flat also cross through the reef slope biotope. Much of the hook and line fishing that occurs in the shallows fronting

Fort Kamehameha is focused in the reef slope habitat seaward of the reef crest suggesting that many of the target species favor this biotope.

Our inspection of more depauperate reef slope marine communities further to the west noted the alga, *Acanthophora spicifera* and corals *Pocillopora damicornis, P. meandrina, Porites compressa* and *P. lobata* with coverage less than 0.1%. Invertebrates seen include the featherduster worm (*Sabellastarte sanctijosephi*), anthozoan (*Zoanthus pacificus*), hydrozoan (*Halocordyle disticha*), sea urchins (*Echinothrix diadema, Diadema setosum, Echinothrix calamaris, Echinometra mathaei, E. oblongata* and *Tripneustes gratilla*), and the black sea cucumber (*Holothuria atra*). Common fishes included the eleotrid (*Asterropteryx semipunctatus*), moano (*Parupeneus multifasciatus*), hinalea lauwili (*Thalassoma duperrey*), 'omaka (*Stethojulis balteata*), boxfish or moa (*Ostracion meleagris*), mamo (*Abudefduf abdominalis*), pualu (*Acanthurus xanthopterus*) and puhi laumilo (*Gymnothorax undulatus*).

Inspection of the dredged face of the Pearl Harbor entrance channel at several sites noted coral species including *Porites compressa, Montipora verrucosa,* and *M. patula* (most abundant was *Montipora verrucosa* with local coverage up to 5% in areas examined). Also seen were sponges (*Halichondria coerulea, Tedania macrodactyla, Mycale cecilia, Zygomycale parishi* and *Toxadocia violacea*), polychaetes (*Sabellastarte sanctijosephi, Branchiomma nigromaculata, Chaetopterus variopedus*), wana (*Echinothrix diadema* and *Diadema setosum*), and green urchin (*Echinometra mathaei*). Fishes seen include the sharpback puffer (*Canthigaster jactator*), hinalea lauwili (*Thalassoma duperrey*), blacktail snapper or to'au (*Lutjanus fulvus*), and the brown cardinalfish or upapalu (*Foa brachygramma*). One green sea turtle (*Chelonia mydas*) was found resting along the channel wall at a depth of 10 m. This turtle had an estimated straight-line carapace lenght of 70 cm and appeared to be free of fibropapilomas (tumors) and did not have any external tags.

B. Biotope of Rubble

The biotope of rubble is located east of the Pearl Harbor entrance channel sandwiched between the reef slope biotope and the biotope of limestone and corals (see Figure 2). Water depths in this biotope range from about 2.5 to 4 m. As the name implies, the substratum of this biotope is dominated by coralline rubble interspersed by occasional emergent limestone areas. For the most part, the exposed limestone appears to be relatively scoured and free of most corals and macroinvertebrates. The limestone areas

range in dimensions from 1 x 4 m to more than 5 x 8 m and, in general, there is little cover present for fishes or macroinvertebrates.

Benthic species seen in this biotope include algae (*Lyngbya majuscula, Dictyota bartayresii, Padina* spp., *Sargassum polyphyllum, Acanthophora spicifera, Hydrolithon reinboldii,* and *Porolithon onkodes*), sea urchins (*Tripneustes gratilla, Echinothrix diadema, E. calamaris,* and *Echinometra mathaei*), octopus or he'e (*Octopus cyanea*), leopard cone (*Conus leopardus*), crabs (unidentified xanthids and *Thalamita edwardsi*) and the sea cucumbers (*Holothuria atra* and *Actinopyge mauritiana*). Few fishes were seen probably because of the lack of cover in this biotope. Among the fish species seen were the 'omaka (*Stethojulis balteata*), hinalea lauwili (*Thalassoma duperrey*), juvenile uhu (*Scarus sordidus*) and a single juvenile omilu (*Caranx melampygus*). In summary, this biotope appears to be relatively depauperate probably related to little topographical relief present and exposure to occasional high energy (wave) conditions which would retard the development of most elements of the benthic community.

C. Biotope of Limestone and Corals

Seaward of the biotope of rubble is the biotope of limestone and corals. The biotope of limestone and corals extends seaward to at least a depth of 13 m and in line with the seaward edge of the Honolulu International Airport Reef Runway. The substratum in the biotope of limestone and corals is dominated by old limestone. This hard bottom substratum is bisected by grooves or channels with a general orientation that is perpendicular to shore. These channels vary greatly in dimensions; widths range from 1 to 8 m, lengths range in excess of 25 m and depths are from 0.5 to 1.7 m. These channels are spaced from 3 to over 10 m apart. Small corals are usually found on the elevated ridges between channels and coverages vary considerably. Nowhere are corals particularly abundant on this large flat comprising less than 10% of bottom cover.

Two locations in this biotope were examined by SCUBA; one at a depth of 5 m (site A, Figure 2) and the second at a depth of 11 m (site B, Figure 2). The results of these inventories are given below.

Site A is at a depth of 5 m and the substratum is limestone bisected by old "spur and groove" formations. The spurs or ridges are from 2 to 10 m wide and up to 25 m in length and these spurs are spaced from 3 to 15 m apart. Intervening channels are from 1 to 5 m wide and up to 1.5 m deep. Dominant corals include *Porites lobata* and *Pocillopora meandrina* with an overall coverage between 5 to 8%. Other coral species

seen include *Montipora verrucosa, M. patula, Pocillopora damicornis, Pavona varians,* and *Porites compressa* but these species contribute little to the overall coverage. Other invertebrate species seen include the swimming crab *Chardybis erythrodactylus,* cone shells (*Conus lividus* and *C. ebreus*), hermit crab (*Dardanus* sp.), reticulated cowry (*Cypraea maculifera*), slipper lobster or ula'papa (*Paribaccus antarcticus*), banded shrimp (*Stenopus hispidus*), sea cucumbers (*Holothuria atra* and *Actinopyge mauritiana*), and sea urchins (*Tripneustes gratilla, Echinometra mathaei, Echinothrix diadema* and *Echinostrephus aciculatum*).

Because the spur and groove formations with the associated corals provide shelter, a number of fish species were seen at site A. These species include the brown surgeonfish or ma'i'i'i (*Acanthurus nigrofuscus*), convict tang or manini (*Acanthurus triostegus*), orangespine surgeonfish or umaumalei (*Naso lituratus*), goldring surgeonfish or kole (*Ctenochaetus strigosus*), saddleback wrasse or hinalea lauwili (*Thalassoma duperrey*), aki'lolo (*Gomphosus varius*), wrasses (*Macropharyngodon geoffroyi* and *Haliochoeres ornatissimus*), palenose parrotofish or uhu (*Scarus psittaceus*), bulletnose parrotfish or uhu (*Scarus sordidus*), spectacled parrotfish or uhu ahu'ula (*Scarus perspicillatus*), stareye parrotfish or ponuhunuhu (*Calotomus carolinus*), sidespot goatfish or malu (*Parupeneus pleurostigma*), doublebar goatfish or munu (*Parupeneus bifasciatus*), manybar goatfish or moano (*Parupeneus multifasciatus*), blue goatfish or moano kea (*Parupeneus cyclostomus*), moorish idol or kihikihi (*Zanclus cornutus*), squaretail filefish or 'o'ili lepa (*Cantherhines sandwichiensis*), reef triggerfish or humuhumu nukunuku a'pua'a (*Rhinecanthus rectangulus*), sharpback puffer (*Canthigaster jactator*), spiny puffer or kokala (*Diodon holocanthus*), damselfishes (*Chromis vanderbilti* and *Stegastes fasciolatus*), hawkfishes or hilu piliko'a and piliko'a (*Paracirrhites forsteri* and *P. arcatus*), longnose butterflyfish or lauwiliwili nukunuku'oi'oi (*Forcipiger flavissimus*), fourspot butterflyfish or lau-hau (*Chaetodon quadrimaculatus*), multiband and the raccoon butterflyfishes or kikakapu (*Chaetodon multifasciatus* and *C. lunula*).

It should be noted that a considerable amount of monofilament netting was found scattered throughtout this inner part of the biotope of limestone and corals suggesting that a reasonable amount of such fishing must occur in the area.

Site B was established at a depth of 11 m just inshore and adjacent to one of the buoys marking the eastern side of the Pearl Harbor entrance channel. Again the substratum was limestone with some irregular channels cut into it having a general orientation perpendicular to shore. These channels are from 1 to 5 m in width, to 1 m in depth and

up to 40 m in length and are generally filled with sand and rubble. The channels are spaced from 6 to 20 m apart. Some corals are found on the intervening limestone ridges; dominant species are *Porites lobata* and *Pocillopora meandrina* with mean cover less than 5%. Close to the entrance channel one 5 x 40 m area was examined where corals were more abundant. In this area were *Pocillopora meandrina, P. eydouxi, Porites lobata, Montipora verrucosa, M. patula,* and *Pavona varians* and coverage was about 25% overall. Other benthic species seen include the coralline algae (*Porolithon onkodes* and *P. gardineri*), sea cucumbers (*Holothuria atra* and *Stichopus* sp.), spiny lobster or 'ula (*Panulirus marginatus*), black shrimp (*Saron marmoratus*), cone shell (*Conus miles*), sea urchir,s (*Tripneustes gratilla, Echinothrix calamaris, E. diadema,* and *Echinometra mathaei*), and the anthozoan *Palythoa tuberculosa.*

Fishes seen in this inventory of site B include orangespine unicornfish or umaumalei (*Naso hexacanthus*), spotted unicornfish or kala lolo (*Naso brevirostris*), sleek unicornfish or kala holo (*Naso hexacanthus*), brown surgeonfish or ma'i'i'i (*Acanthurus nigrofuscus*), orangebar surgeonfish or na'ena'e (*Acanthurus olivaceus*), convict tang or manini (*Acanthurus triostegus*), yellow tang or lau'ipala (*Zebrasoma flavescens*), goldring surgeonfish or kole (*Ctenochaetus strigosus*), hawkfishs or hilu piliko'a and piliko'a (*Paracirrihites forsteri, P. arcatus,* and *Cirrhitops fasciatus*), lei triggerfish or humuhumu lei (*Sufflamen bursa*), fantail filefish or 'o'ili'uwi'uwi (*Pervagor spilosoma*), saddleback wrasse or hinalea lauwili (*Thalassoma duperrey*), belted wrasse or 'omaka (*Stethojulis balteata*), cleaner wrasse (*Labroides phthirophagus*), ornate wrasse (*Haliochoeres ornatissimus*), bird wrasse or aki'lolo (*Gomphosus varius*), yellowtail wrasse or hinalea aki'lolo (*Coris gaimard*), shortnose wrasse (*Macropharyngodon geoffroyi*), sharpback puffer (*Canthigaster jactator*), manybar goatfish or moano (*Parupeneus multifasciatus*), damselfishes (*Chromis agilis, C. vanderbilti, Stegastes fasciolatus,* and *Plectroglyphidodon johnstonianus, Dascyllus albisella*), angelfish (*Centropyge potteri*), longnose butterfly fish or lauwiliwili nukunuku'oi'oi (*Forcipiger flavissimus*), teardrop butterfly fish or lau-hau (*Chaetodon unimaculatus*), and the multiband, blacklip and threadfin butterflyfishes or kikakapu (*Chaetodon multicinctus, C. kleinii, C. auriga*).

Discussions with several fishermen point out that many commercially valuable species are taken in the vicinity of site B. These include most of the species noted in the reef flat biotope as well as mackeral scad or opelu (*Decapterus macarellus*) and the big-eye scad or akule (*Selar crumenophthalmus*). Several green sea turtles (*Chelonia mydas*) were seen in the biotope of limestone and corals. These turtles were probably in their diurnal resting habitat, usually selecting some area with appropriate shelter characteristics for resting during the day. Foraging probably takes place inshore of the

resting areas such as on the reef flat where algae are abundant and usually under the cover of darkness.

D. Deep Offshore Biotope

At the most seaward areas of the survey (37 m), bottom composition consists almost entirely of gray sand. In many areas the sand exhibited ripple marks indicating resuspension and movement by currents. In other areas the sand surface was flat and covered with a greenish film, most likely consisting of benthic diatoms. Existence of benthic films suggests little movement of sediment by wave and current forces. Moving shoreward, the sand bottom grades gradually into a sand/rubble mixture. Rubble fragments appear to be primarily the remains of reef corals that had probably been broken from the reef by storm or hurricane waves.

Interspersed across the bottom within the sand/rubble habitat are features that might be termed "patch reefs". These structures are not true "reefs" in that there is not an upward accreting solid limestone platform. Rather, these areas consist of denser aggregations of limestone rubble with a component of living corals. The dominant corals on these patch reefs are *Porites compressa, Porites lobata, Pocillopora meandrina* and *Montipora verrucosa.* Growth forms of most of the corals on these patch reefs consisted of flat encrustations, and massive lobed colonies. Thus, while the patch reefs had a substantially higher vertical relief than the sand plain, there is not marked vertical relief of greater than approximately 25-50 cm. Living coral cover on the patch reefs is estimated on the order of 10-20%. Integrated over the entire sand/rubble plain, the patch reefs may comprise approximately 5-10% of bottom cover, while living coral cover is estimated at less than 2-5% of bottom cover.

These reefs provide habitat for a variety of reef fish, particularly butterflyfish (Chaetodontidae), goatfish (Mullidae), wrasses (Labridae), damselfish (Pomacentridae), surgeon fish (Acanthuridae) and triggerfish (Balistidae). Most of the fish observed in the survey were juveniles or small adults. Other dominant biota observed on the sea urchins *Heterocentrotus mammilatus, Echinometra mathei, Echinothrix diadema,* and *Tripneustes gratilla.*

E. Evaluation of Proposed Outfall Route

A tentative outfall route has been selected that extends approximately 1100 m from the shoreline near the WWTP across the reef flat (Figure 3). At the edge of the reef flat, the

outfall pipe will drop down the wall of the Pearl Harbor entrance channel and will continue seaward for approximately 2500 m to the diffuser site at a depth of 45 m. On the reef flat, water depth along the route ranges from approximately 0.3 m at low tide to 1 m at high tide. Proposed construction techniques will involve driving equipment directly onto the reef flat; no berm will be constructed. The construction corridor, delineated by silt containment curtains, will be approximately 15 m wide. A trench approximately 3 m wide will be excavated, and lined with crushed gravel will accommodate the 42" pipe. Weighted concrete collars and crushed gravel will hold the pipe in place. Articulated concrete mats extending the width of the trench will be placed over the backfill to protect the pipe, which in turn will be covered with native material to the level of the existing bottom. Through the channel, the pipe will be buried in a trench and covered with tremie concrete. Beyond the channel, the pipe will be supported over the sand bottom on driven or jetted piles.

One criterion of selecting this route was that it appeared to contain the lowest coverage of living reef coral communities compared to other routing alternatives. Follow-up semi-quantitative surveys were conducted by investigators walking the proposed route to evaluate existing biotic composition. These evaluations focus on coral coverage because reef corals are considered to be "keystone" species that provide both physical structure (shelter) and food sources for associated components of the community.

From the shoreline point of departure, the pipeline corridor extends across the inner reef across a large sand patch to the channel cut. As discussed in the sections above, benthic biota on the inner reef flat consists mainly of algae and motile invertebrates. Corals are very rare or nonexistent through the majority of the route between the shoreline and the sand patch. From the sand patch to channel bottom composition consists mainly of rubble lying on a thin layer of coarse sand that covers the limestone platform. Living corals in this area were all small colonies growing on rubble fragments. No large colonies (greater than 0.3 m in any dimension) or microatolls were observed within the proposed boundaries of the construction corridor. Coral species observed were *Pocillopora damicornis, Porites compressa, P. lobata,* and *Montipora verrucosa.* All of these species are common on Hawaiian reefs and are not rare or unique species.

The reef crest in the pipeline corridor does not encompass any areas of substantial coral growth. From the reef crest to the channel slope, the bottom consists entirely of rubble fragments with virtually no living corals. Along the vertical face of the channel

cut, patches of encrusting *Montipora verrucosa* and *M. patula* occurred. No corals were encountered on the channel floor.

At a length of 1,160 m, and a width of 15 m, the total construction footprint from the shoreline to the channel floor is 17,400 m^2. It was estimated that the total coral coverage within this corridor is less than 10 m^2. Hence, living coral constitutes approximately 0.06% of bottom cover.

DISCUSSION - ANALYSIS OF IMPACTS

Two types of potential impacts to marine communities can be considered with respect to the proposed construction of the Fort Kamehameha sewage discharge pipe. One type of impact is associated with the actual construction of the discharge pipe; the second type of impact may result with the subsequent operation of the discharge system. The effects from construction may be considered a short-term impact, while the effects from operation may be considered a longer term influence.

As a point of departure, it should be noted that there were no rare or endangered marine species noted in this survey. However, both the burrowing polychaete *Arenicola brasiliensis* and the alga *Gracilaria salicornia* are not commonly seen around O'ahu, probably because these species prefer shallow low-energy habitats. *Gracilaria salicornia* has been observed by the authors, however, in high density in other regions of Pearl Harbor (off Pearl City Peninsula). The threatened green sea turtle (*Chelonia mydas*) was observed in its resting habitat and is a common species in the vicinity of the Pearl Harbor entrance channel as well as both to the east and west of this channel. In fact, past observations by the authors of the existing sewage discharge pipe along the eastern edge of the Pearl Harbor entrance channel reveal that the gap between the pipe and the channel floor appears to be a favored resting habitat that is usually occupied by numerous small turtles. Thus there is nothing unusual about the presence of green turtles in the study area.

Impacts Associated with Construction of the Discharge Pipe

Construction plans call for burial of the discharge pipe across the shallow reef flat. The construction specifications also call for the replacement of the same substratum as presently exists in each area once trenching and pipe deployment has been completed. Burial appears advantageous because it will protect the discharge pipe from damage from occasional storm waves, and once constructed, will presents no visual impact

when viewing across the shallow reef flat. Obviously benthic communities in the direct path of the selected route will be destroyed. Therefore it was important to select the route through areas that have the either the greatest levels of ongoing ecological disturbance and/or are the most depauperate (i.e., those communities with the fewest organisms of the lowest diversity).

While removal of marine communities in the construction corridor of the discharge pipe will occur, all of the species noted in this area are common elements of Hawaiian reefs and should be able to reproduce and recolonize substratum with the same physical characteristics as presently exists. Thus, the upper layer of substratum (sand, rubble or rock) will be restored to the same composition that existed prior to the commencement of construction in the area. As the construction corridor comprises less than 1% of the entire reef flat, there appears to be ample area to provide potential recolonizers. Following the specification of replacing existing substratum should afford any benthic species removed by construction the opportunity to recolonize following completion of the project.

Construction will require trenching and stockpiling of dredged material which will create fine sediment which could be carried by currents to surrounding benthic communities where it may settle and create problems for benthic species. Sediment in the water column may decrease light levels, lowering local productivity. If the sediment settles, it may interfere with feeding and respiratory mechanisms of benthic species and species such as corals which have mechanisms for cleaning their surfaces of sediment may have to expend more energy in this process. If the sediment loading is great enough, it may overwhelm the cleaning mechanisms of the benthic species resulting in burial and death.

The effects of sediment stress to corals have been extensively reviewed by Johannes (1975), Dodge and Vaisnys (1977), Bak (1978), Brown and Howard (1985) and Grigg and Dollar (1989). In summary, while it is clear that increased sedimentation can have a deleterious effect on corals, particularly when buried, increased sedimentation, especially of a temporary duration) can also result in no negative impacts. Because sediments are a natural component of most marine environments and are suspended by natural processes, most corals are adapted to withstand a certain level of sediment supply to the living surface. Many species have the ability to remove sediment from their tissues by ciliary action or the distension of the coenosarc with water, both of which can nullify the lethal effects of sedimentation (Yonge 1931).

In case studies of the effects the sedimentation, the range of environmental effects varies through the entire spectrum of stress. Cases where effects of dredging have caused mortality have generally limited to areas of confined circulation such as Castle Harbor, Bermuda (Dodge and Vaisnys 1977), and Kaneohe Bay, Hawaii (Banner 1974). In area of unrestricted circulation, however, there have been instances of increased sedimentation reported that do not appear to cause any substantial effects of reefs. Sheppard (1980) reported that following dredging and blasting for a military harbor in Diego Garcia Lagoon, coral cover appeared to show no effects from increased siltation. In Hawaii, there are several documented cases where increased sedimentation from excavation projects caused no effects to neighboring coral communities. These cases include blasting and construction of Honokohau Harbor (U.S. Army Corps of Engineers 1983), Kawaihae Deep Draft Harbor (ORCA 1978). Dollar and Grigg (1981) studied the fate of benthic communities at French Frigate Shoals in the Northwestern Hawaiian Islands following the accidental spill of 2,000 tons of kaolin clay. These authors found that after two weeks there was no damage to the reef corals and associated communities except where the organisms were actually buried by the clay deposits for a period of more than two weeks. Excavation of a shallow nearshore reef flat in Kaneohe Bay for construction of a revetment to control shoreline erosion at the Marine Corps Base Hawaii also was shown to cause substantial, but temporary increases in suspended sediment that caused no detectable negative effects to mature coral communities that were adjacent to the construction site (Marine Research Consultants 1996). As the coral communities in all of these case studies were substantially richer than those observed on the Fort Kamehameha reef, it is likely that the impacts associated with construction of the discharge pipe should not be significant.

Activities associated with the construction and deployment of the discharge pipe will not only cause sediment plumes but also will create noise underwater. Such noise could either serve to disperse motile species escaping from the sound and vibration, or could serve to attract other species. An example of attraction occurred at West Beach, Ewa, O'ahu where green sea turtles moved their resting habitat from a ledge more than a kilometer from shore to a point about 200 m seaward of shoreline construction that included dredging of four swimming lagoons (Brock 1988). Noise and vibration from the construction work would be a transitory impact to marine communities in the vicinity of Pearl Harbor. It should also be remembered that Pearl Harbor is the largest naval port in the Pacific and considerable shipping moves in and out of the harbor on a daily basis. This shipping as well as that from the commercial vessels moving by seaward of the harbor all contribute to the relatively high level of background noise in this area.

Thus the extant marine communities are those that have colonized this area despite relatively high noise levels created by high vessels traffic.

Green sea turtles feed on a variety of macroalgae species including many of those found in the reef flat biotope (see Balazs 1980 and Balazs *et al.* 1987). An overall estimate of algal coverage on the reef flat is about 10%, with the majority of coverage consisting of of the introduced species, *Acanthophora spicifera.* A 10% coverage translates into about 70,000 square meters or 7 ha of the reef flat being covered with macroalgae and this macroalgae has a reasonably uniform distribution across much of the reef flat. A conservative estimate of *Acanthophora spicifera* coverage is 75% of the total reef coverage. Thus, this species occupies about 49,000 square meters (4.9 ha) of the reef flat. *Acanthophora spicifera* is an important forage species for Hawaiian green turtles (Balazs *et al.* 1987). If construction trenching involves disturbance of an estimated 1% of the entire reef flat (a very generous estimate), it may temporarily remove about 500 square meters of *Acanthophora spicifera*; 48,500 square meters would be undisturbed. Such a level of coverage insures that even with construction activities, a more than adequate supply of macroalgae forage should be available to green turtles.

Impacts with Discharge Pipe Operation

The Fort Kamehameha WWTP presently discharges secondarily treated wastes into the Pearl Harbor entrance channel at a point about 540 m seaward of the plant. The proposed discharge pipe will take this material about 3.1 km further seaward, well away from the Fort Kamehameha reef flat and shallow subtidal areas just seaward of it.

Our studies of the Fort Kam reef commenced in 1972. Review of field notes from that time indicate that almost all benthic species noted in this inventory were present at that time on the reef in abundances very similar to what is encountered there today. The qualitative data suggest that the marine communities have been relatively stable and persistent for the last 24 years. The present Fort Kamehameha WWTP was put into operation in 1970 and despite the discharge of treated effluent in relatively close proximity of the these communities, no obvious changes are evident. This information suggests that the discharge of treated effluent has not caused any progressive shifts in community structure as a result of changes in water chemistry. Relocation and operation of the discharge from the inner entrance channel area to a point more than 3 km seaward should have no noticeable impact on the marine communities examined in this study.

If any impact is to occur with the relocation of the discharge to a point further seaward, it probably would be with a lowering of nearshore nutrient input and a possible decrease in abundance of algae on the on the Fort Kam reef flat. An estimate of the contribution of nitrite-nitrate nitrogen, total nitrogen and total phosphorus from the Fort Kam WWTP and from nonpoint sources in Pearl Harbor is given by Stevenson and O'Connor (1996). Of the total flow or discharge of water entering Mamala Bay from Pearl Harbor, the Fort Kam WWTP provides less than 5 percent; for nitrate nitrogen the STP provides 27 percent of the total, total nitrogen it is 21 percent of the total, and for total phosphorus it is 28 percent of the total discharging from the harbor into Mamala Bay.

Laws and Ziemann (1996) found relatively high nitrate and phosphate concentrations at the Fort Kamehameha beach park adjacent to the WWTP. These authors attribute the elevated values to the proximity of the Fort Kamehameha effluent discharge. These data suggest that the operation of the plant may be contributing to the growth of algae on the shallow reef flat. However, the Laws and Ziemann study was severely flawed in that only a single sampling point was used that was adjacent to the Hickam Boat Harbor, and upcurrent from the predominant direction of flow of water from the Pearl Harbor channel. Thus, there is no way to conclude from the data that the discharge of the Fort Kamehameha outfall was affecting nutrient concentrations at the beach park. In any event several points should be made relative to findings of Laws and Ziemann; these are: (1) the dominant algal species in the study area is *Acanthophora spicifera* which is a non-native species having arrived in the Hawaiian Islands about 1950. Thus, any change would be primarily to an introduced (i.e. unwanted) species. This species has been observed to occur in massive abundance on other reef flats in Hawaii that are not adjacent to sewage discharges; (2) any change in the abundance of algae on the Fort Kamehameha reef flat is predicated on the nutrients from the present discharge being carried to the northeast up on the reef flat; this would be a very unusual direction for the local current to flow which is tradewind-driven and generally moves in a directly opposite direction (to the southwest); (3) the idea that there would be a decrease in the abundance of algae on the Fort Kamehameha reef flat because of the removal of the discharge to a more offshore location ignores any input from non-point sources along the shoreline. It should be noted that during our field studies groundwater discharge to the reef flat was evident at several locations along this shoreline. These non-point discharges could certainly result in a local elevation of nutrients in the inshore waters fronting the Fort Kamehameha beach park. Thus removal of the Fort Kamehameha WWTP discharge from the inshore site should have little if any impact on the source(s) of nutrients for algae on the shallow nearshore reef flat.

Delineation of Depauperate Areas

The biota of the Fort Kamehameha reef flat is very similar to that found on the shallow reef flats just east of the Honolulu International Airport reef runway and extending to the western edge of Sand Island. This entire reef complex has received considerable disturbance over the last 100 years including dredging and filling, high nutrient loading from point sources and numerous non-point source inputs from urban and industrial areas of Honolulu. From an ecological perspective, perhaps one of the most evident forms of disturbance to these shallow communities has been the successful introduction of a number of non-native species that are often competitively superior space occupiers. Some of these species are algae and have come to dominate the shallow benthic communities, probably displacing numerous native species in doing so. The Fort Kamehameha reef flat has received all of these forms of disturbance since the turn of the century and other than the removal of these shallow benthic communities by dredging and/or filling (e.g., Hickam Harbor, reef runway), the most obvious lasting impact has been the introduction and dominance of non-native algae.

If these disturbed communities are considered to have less ecological value because of the displacement of native species, etc., much of the Fort Kamehameha reef flat would qualify as having lower ecological value. Thus construction and deployment of the new discharge pipe through the reef flat biotope would probably have little negative impact insofar as native shallow marine communities are concerned. Similarly, biological development appears to be low in the biotope of rubble seaward of the reef flat. Construction activities in this biotope would have relatively little negative impact.

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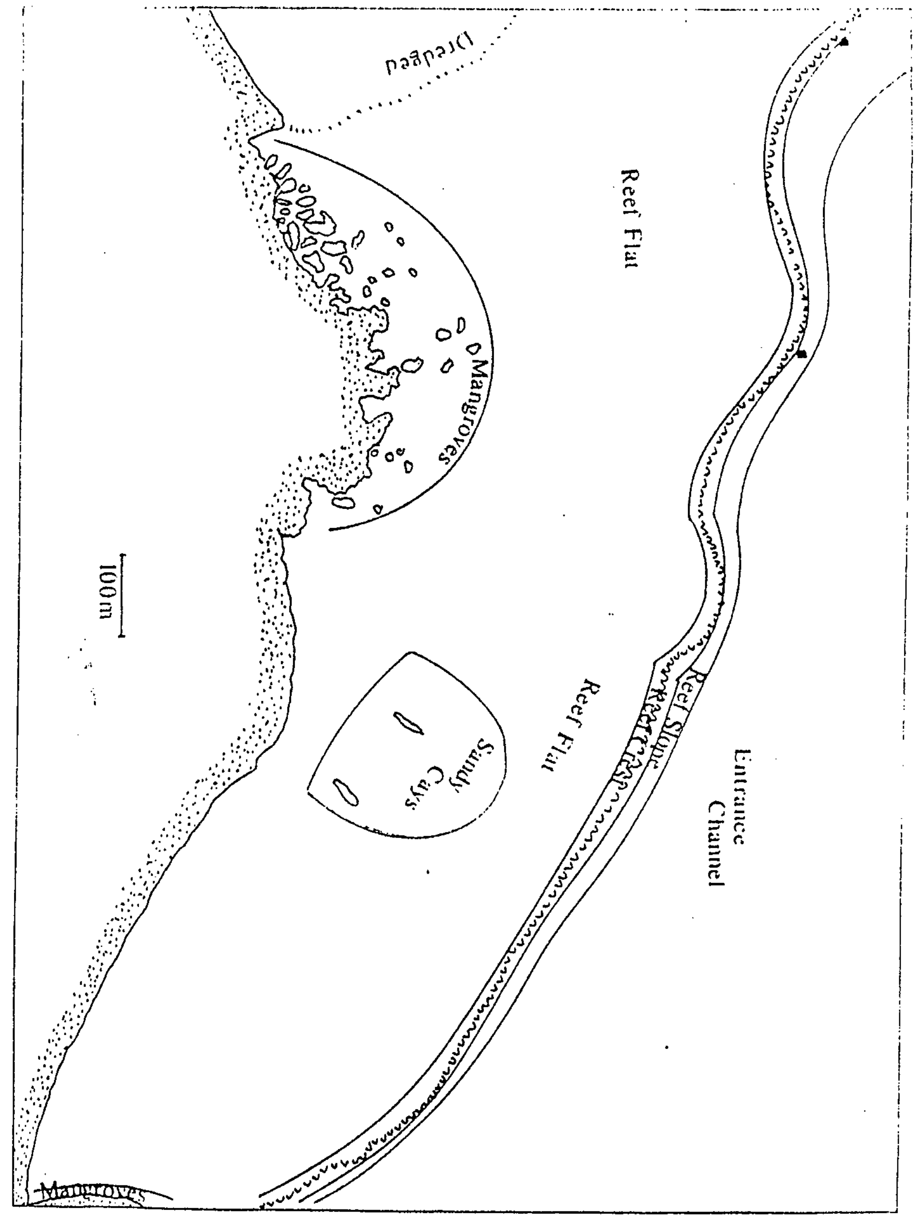

Figure 1. Map of the reef area fronting the Fort Kam and four biotopes identified in the shallows. These biotopes are the reef flat biotope, the biotope of mangroves, the biotope of sandy cays, the reef crest biotope and the reef slope biotope. Also shown is the reef slope biotope which is described in a subsequent section. The shoreline is stippled; two concrete structures just seaward of the reef crest in the eastern part of the study area are shown as small dark squares and are included as points of reference. Map redrawn from an aerial provided by Sea Engineering, Inc.

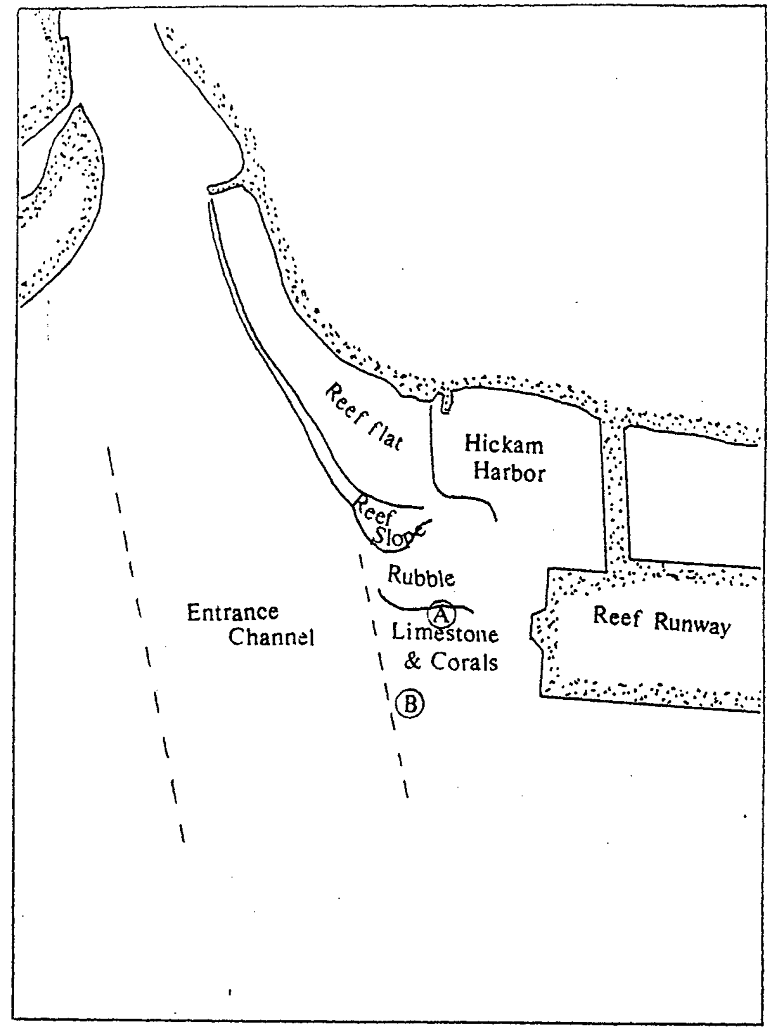

Figure 2. Map of the Fort Kam reef, the Pearl Harbor entrance channel, the western portion of the Honolulu International Airport reef runway and Hickam small boat harbor. Also given are the approximate boundaries of biotopes seaward of the reef crest. These biotopes are the reef slope biotope, the biotope of rubble and the biotope of limestone and corals. Also shown are the approximate locations of two areas (circled "A" and "B") qualitatively examined in the biotope of limestone and corals. The shoreline is stippled; scale is 1:24,000. Map based on USGS quadrangle series.

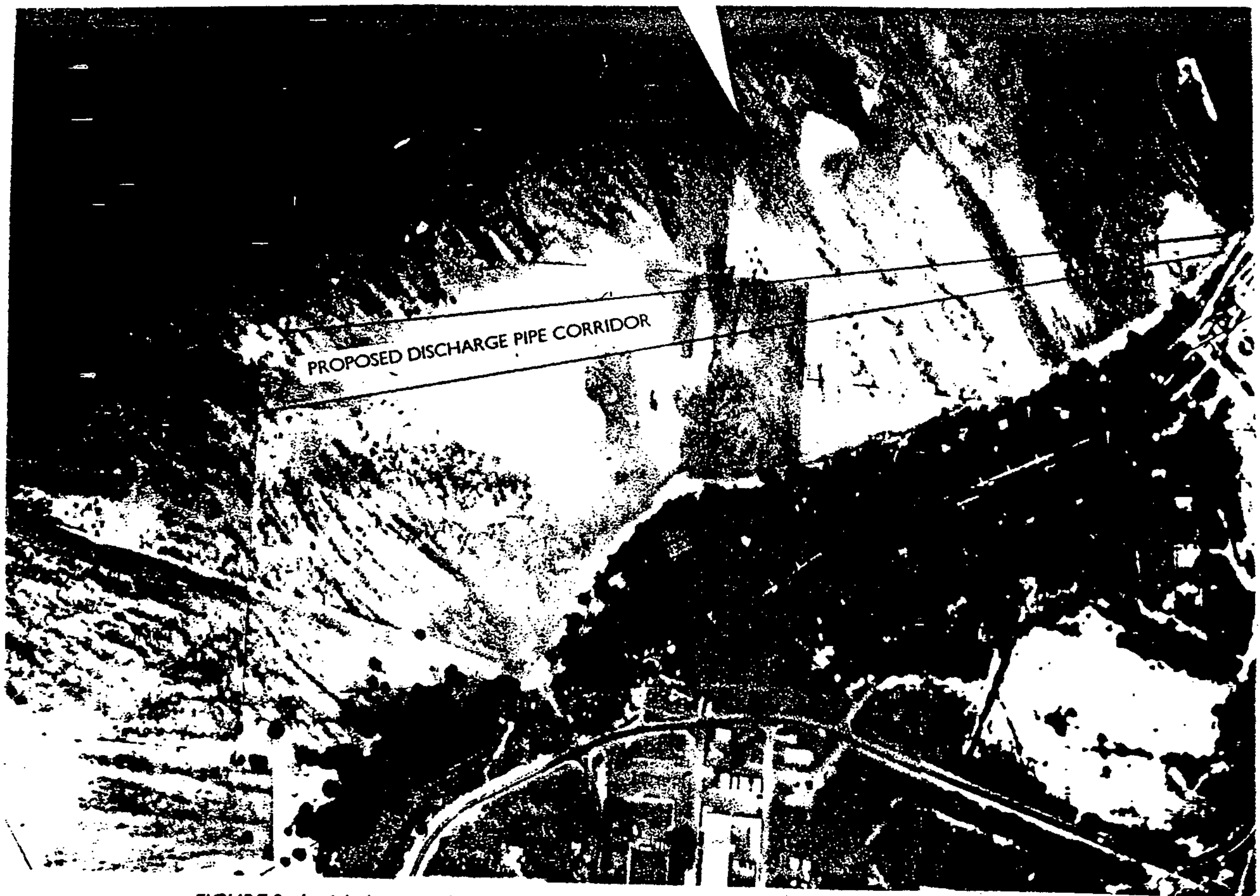

FIGURE 3. Aerial photograph of Fort Kamehameha reef showing proposed location of discharge pipe corridor originating at the Fort Kamehameha Treatment Plant and crossing the reef flat. At the juncture of the reef flat and the Pearl Harbor entrance channel, the discharge pipe drops to the channel floor and continue seaward along the eastern edge of the channel.

FIGURE 3. Aerial photograph of Fort Kamehameha reef showing proposed location of discharge pipe corridor originating at the Fort Kamehameha Treatment Plant and crossing the reef flat. At the juncture of the reef flat and the Pearl Harbor entrance channel, the discharge pipe drops to the channel floor and continue seaward along the eastern edge of the channel.

Appendix VIII

Assessment of Biotic Communities on the Proposed Alignments for the Fort Kamehameha Sewage Outfall Extension

ASSESSMENT OF THE BIOTIC COMMUNITIES ON THE PROPOSED ALIGNMENTS FOR THE FORT KAMEHAMEHA SEWAGE OUTFALL EXTENSION

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I. INTRODUCTION

The proposed extension of the outfall pipe for the upgraded Fort Kamehameha Sewage Treatment Plant will transit the reef flat bordering the east side of the Pearl Harbor entrance before extending into deeper offshore waters where the diffuser will be located. Considerations of the route of the outfall depend on construction issues as well as concerns to minimize alterations to the marine environment. Owing to the discovery of unsuitable substratum for anchoring of the pipe along the original proposed alignment along the edge of the Pearl Harbor channel, alternate routes have been investigated. The purpose of this report is to describe the composition of the marine habitats on the reef flat along several proposed alignments, along with the objective of describing the environmental alterations that might accompany the proposed construction activity.

II. METHODS

To identify the proposed outfall routes, marker buoys were placed on the reef. Exact placement of the buoys was accomplished by taking coordinates of the stations along the proposed route from bathymetric charts and marking these locations on the reef using Differential Global Positioning System. The array of buoys allowed ground surveys to be very specific regarding biotic composition and substratum type on the exact outfall alignments. Buoys were labeled as follows: FK-1 just seaward of the sandbar on the inner reef flat; FK-2 between the sandbar and the microtunnel jacking pit; FK-3 at the proposed site of the jacking pit, and FK-4 at the seaward end of the microtunnel leg. Surveys were conducted by investigators walking the entire route from the shoreline to the location of the proposed microtunnel jacking pit (FK-3). At selected points along the alignment quantitative assessments of biotic composition were conducted by enumerating organisms within a 2 m wide band oriented perpendicular to the alignment for a distance of 20-30 m. At the location of the jacking pit, three additional transects were conducted parallel to the alignment. Each of these transects was 30 m long; one transect was conducted at the eastern boundary of the jacking pit; one transect was conducted in the outfall alignment at the center of the jacking pit; and the third transect was conducted along the channel wall at the western boundary of the proposed barge access channel to the jacking pit. In addition, quantitative assessments of biota were made using SCUBA at FK-4 as well as three other locations along the proposed alignment on the channel wall seaward of the point where the outfall emerges from the microtunnel (FK-5,6,7). A qualitative survey was also conducted in the area of a proposed corridor for truck transit from the shoreline to the vicinity of FK-1 in order to determine suitability for use during construction of the outfall.

Organisms denoted during the surveys were limited to diurnally exposed "macrobiota" (i.e., larger than 2 cm in some dimension). In addition, no attempt was made to identify the microalgae which are a common component of the benthos of most coral reefs.

III. RESULTS

Overall, the entire reef flat bounded by the Hickam Peninsula to the east and the Pearl Harbor entrance channel to the west is composed of a shallow fossil

limestone bench covered with a veneer of sand and coral rubble. While live corals occurred commonly in some localized areas of the reef flat, their overall abundance is considered low for the entire area (<1%). Of note, however, is the substantial quantity of coral rubble fragments and dead, but intact, coral structure over the outer portions of the reef flat. The occurrence of such material indicates that either coral cover was substantially higher in the recent past, and was significantly reduced by catastrophic events such as Hurricanes Iwa and Iniki. Alternatively, rubble fragments originating from corals growing in deeper water beyond the reef flat were dislodged by these same catastrophic events and were transported to the reef flat by wave action.

Presented below are descriptions of the specific areas of the proposed outfall alignment.

1. Shoreline Entry of Outfall Pipe location to FK-1

Water depth in this interval is very shallow, generally less than 0.5 m. Sand and rubble are the dominant substratum type in this area. The visually dominant species seen is the introduced alga *Acanthophora spicifera* attached to pieces of coralline rubble. Overall the algal cover of *Acanthophora* is between 15-20% . Other algal species present are *Padina japonicum, Tolypiocladia* sp., *Spyridia filamentosa, Hypnea cervicornis, Coelothrix irregularis, Enteromorpha* sp. and *Gracilaria* spp. Macroinvertebrate species seen include the tunicate *Didenum candidum,* orange sponge (*Microciona maunaloa*), crab (*Thalamita edwardsi*), and green sea urchin (*Echinometra mathaei*). Fishes seen include juveniles of the saddleback wrasse or hinalea lauwili (*Thalassoma duperrey*) and the belted wrasse or 'omaka (*Stethojulis balteata*). All of these fishes were species that are common in similar habitats. None of the fish observed were abundant in the areas surveyed.

2. FK-1 to FK-2

The area from buoy FK-1 seaward to a distance of 70 m is similar to interval 1. Within the region between approximately 50 m and 200 m from FK-1 occurs an array of living "microatolls" composed primarily of large single colonies of the stony coral *Porites compressa* (commonly called finger coral). These microatolls are so named because they develop in the similar fashion as a true atoll. Single colonies grow in a circular mode laterally, but are limited in upward growth by the shallow water depth at low tide. With time the living coral polyps are limited to the lateral vertical perimeters of the colonies while the centers of the colonies are bared limestone. The diameter of these microatolls extends from approximately 1 m to 5 m. They become more common in a seaward direction (with increasing water depth). These microatolls are spaced from 5 to 20 m apart, separated by patches of white sand. One microatoll comprised of *Porites lobata* was seen in this area as were the corals *Pocillopora damicornis* and *Pocillopora meandrina.* The microatoll zone was relatively small in length along the outfall alignment (~150 m). Within the microatoll zone, live coral cover was estimated at 15-20% of total bottom cover.

The dominant algal species in this area is *Acanthophora spicifera*; other algae seen include *Dictyosphaeria cavernosa, Microdictyon japonicum, Lyngbya majuscula, Padina thivyi, Sphacelaria furcigera,* and *Spyridia filamentosa.* Invertebrates seen in this area include the ghost shrimp (*Callianassa variabilis*), crab (*Thalamita edwardsi*), featherduster worm (*Sabellastarte sanctijosehpi*), the mantis shrimp (*Gonodactylus falcatus*), brittlestar (*Ophiocoma* sp.) and sea cucumber *Holothuria atra.* In the sand are numerous small holes ranging from about 3 to 8 mm in diameter probably made by a number of cryptic burrowing polychaetes and crustaceans. These holes are spaced from 10 to 30 cm apart and are most evident where the substratum is fine grained sand. Again, most fishes seen in this area were juveniles including *Thalassoma duperrey, Stethojulis balteata,* small parrotfish or uhu (*Scarus sordidus* and *Scarus psittacus*), convict surgeonfish or manini (*Acanthurus triostegus*) and ringtail surgeonfish or pualo (*Acanthurus blochii*).
None of the fish observed were abundant.

Seaward, the area of sand with microatolls is replaced by a mix of coralline rubble, sand and emergent hard substratum. The hard substratum appears to be the remnants of large coral colonies that have been killed and are in a state of decay. These dead coral patches range in size form 1 to 3 m in diameter and are spaced from 1 to 8 m apart with sand and rubble in the intervening area. Much of the dead coral is overgrown by thick mats of *Dictyosphaeria cavernosa* (commonly called bubble algae); also present are the algae *Lyngbya majuscula* and *Acanthophora spicifera.* Invertebrate species encountered here include the shrimp (*Saron marmoratus*), *Holothuria atra,* unidentified xanthid crabs (family

Xanthidae), *Thalamita edwardsi, Gonodactylus falcatus, Ophiocoma* sp., and *Callianassa variabilis.* The same juvenile fish species were seen as previously mentioned. Occasionally, corals are seen growing on elevated parts of the hard substratum; species seen include *Porites compressa, P. lobata, Pocillopora meandrina* and *P. damicornis.* All corals occurring in this area were small in size (less than 20 cm) and uncommon. Total coral cover was less than 1% of bottom cover.

3. FK-2 to FK-3

Just seaward of FK-2 the substratum continues as described just above (i.e., hard substratum in the form of coral colony remnants with sand in the intervening areas. With distance seaward the sandy areas become larger and the dead coral heads less abundant.

Approximately 150 m seaward of FK-2 the algal covered hard substratum changes to a mix of sand-covered hard (limestone) bottom and coralline rubble. On this substratum are scattered small coral colonies with total coverage of 1-2%. Species of coral seen include *Pocillopora meandrina, P. damicornis, Porites compressa* and *Porites lobata*. Also present (in very small amounts) is the soft coral, *Palythoa tuberculosa*. Other exposed invertebrates present on the reef flat are the long spined urchin or wana (*Echinothrix diadema*), banded urchin (*Echinothrix calamaris*), green urchin (*Echinometra mathaei*), black urchins (*Tripneustes gratilla* and *Echinometra oblongata*), sea cucumber (*Holothuria atra*), and polychaete (*Loimia medusa*). The dominant algal species present in the reef crest area is *Acanthophora spicifera*. This sand-rubble biotope with occasional small corals extends to seaward to the location of the jacking shaft (FK-3).

4. Area of Proposed Jacking Shaft (FK-3)

Substratum at FK-3 is comprised of sand and rubble with patches of highly eroded limestone that appear to be the remnants of old coral colonies. These old coral colonies, while devoid of living coral tissue serve as habitat to a number of common reef species. Algae seen on the hard bottom include *Acanthoptera spicifera, Microdictyon japonicum* and *Padina japonicum* having a mean coverage of about 2%.

Buoy FK-3 marks the location of the proposed jacking shaft for the microtunneled portion of the outfall discharge pipe. The jacking shaft will occupy an area approximately 20 m in each direction, with a barge access channel about 25 to 30 m wide that will extend over the edge of the entrance channel. It is expected that this channel will be excavated to a depth of about -6 m down the channel wall. Since there will be some removal of material and disturbance to the marine communities in the area, three 30 m long transects were established to quantitatively ascertain the marine communities present in the area. These transects had an orientation parallel to the entrance channel with the middle of each transect at the midline of the trench. All biota within a band 2 m wide along the length of the transects were enumerated. The first transect (A) was established 15 m east of buoy FK-3 with water depths ranging form 1 to 1.4 m, the second (B) about 15 m west towards the entrance channel having water depths ranging from 1.2 to 2 m, and the third (C) about 8 m west along the 3 to 4.5 m isobath of the entrance channel edge. The results of these transects are presented below. Note that census results are either given as percent cover or counts of individuals for the entire 1 x 20m transect line or counts of individuals per unit area.

Transect A (Water Depth 1-1.4 m)

Algae	
Acanthophora spicifera	0.3%
Padina japonicum	0.4%
Corals	
Pocillopora meandrina	1.8%
P. lobata	0.1%
Other Invertebrates	
Echinometra mathaei	$4/m^2$
Echinothrix diadema	$1/4m^2$
Holothuria atra	$1/10m^2$
Tripneustes gratilla	$1/7m^2$
Sabellastarte sanctijosephi	$1/18m^2$
Fishes	
Stethojulis balteata	10 individuals
Thalassoma duperrey	14 individuals
Acanthurus triostegus	2 individuals

Transect B (Water Depth 1.2-2 m):

Algae	
Acanthophora spicifera	0.2%
Dictyosphaeria cavernosa	0.1%
Corals	
Pocillopora meandrina	2.4%
P. lobata	0.1%
Other Invertebrates	
Echinometra mathaei	$2/m^2$
Echinothrix diadema	$2/3m^2$
Holothuria atra	$1/20m^2$
Tripneustes gratilla	$1/5m^2$
Saron marmoratus	3 individuals
Callianassa variabilis	1 individual
Paribaccus antarcticus	1 individual
Fishes	
Stethojulis balteata	8 individuals
Thalassoma duperrey	13 individuals
Acanthurus triostegus	3 individuals
Acanthurus nigrofuscus	4 individuals
Abudefduf abdominalis	3 individuals
Scarus sordidus	4 individuals
Paracirrhites forsteri	1 individual
Coris venusta	1 individual

Transect C (Water Depth 3-4.5 m):

Corals	
Pocillopora meandrina	4.4%
P. lobata	0.3%
Other Invertebrates	
Echinometra mathaei	$3/m^2$
Echinothrix diadema	$2/m^2$
Holothuria atra	$1/20m^2$
Tripneustes gratilla	$1/7m^2$
Saron marmoratus	4 individuals
Fishes	
Stethojulis balteata	6 individuals
Thalassoma duperrey	16 individuals
Acanthurus triostegus	5 individuals
Acanthurus nigrofuscus	2 individuals
Abudefduf abdominalis	1 individual
Rhinecanthus aculeatus	1 individual
Foa brachygramma	3 individuals
Apogon maculiferus	4 individuals
Chromis vanderbilti	3 individuals
Dascyllus albisella	9 individuals
Gnathanodon speciosus	1 individual (estimated weight 3.5 kg)

It should be noted that Transect C is situated in an area where pieces of limestone ranging in size from 1 x 1 m to 2 x 3 m are scattered over the sloping sand/rubble substratum. These limestone blocks serve as habitat for many of the fishes and invertebrates noted in the censuses above. The yellow jack or pa'opa'o (*Gnathanodon speciosus*) which was in the Transect C census is rather unusual because this predator wanders over wide areas of reef and encounters are by chance.

An alternate site for the jacking shaft (FK-3A) is located on the outfall alignment approximately 150 m seaward of FK-3. Inspection of this area revealed similar substratum type and biotic community structure as described above for FK-3.

5. PEARL HARBOR ENTRANCE CHANNEL (FK4-7)

a. General Considerations

The Pearl Harbor Entrance Channel has been dredged through old limestone reef. This limestone is a relatively continuous feature along the eastern side of the entrance channel to depths of about 20 m. The dredging process left large individual blocks of limestone broken free of the limestone wall and presently situated on the sand-talus slope that occurs between the vertical limestone wall and the sand-covered channel floor. The steep limestone "wall" varies in height from just 1.5 m to well over 5 m in height along the eastern edge. The proposed discharge pipeline alignment exits the microtunnel into a trench along the channel wall that begins at location FK-4. From this point seaward, the proposed

alignment of the discharge pipe follows the eastern side of the entrance channel seaward.

In order to evaluate the potential impacts of the proposed alignment, surveys were conducted at four points along the channel wall (FK-4,5,6,7). At all four sites, large pieces of limestone lay free of the wall on the talus slope. These limestone blocks range in size from about 1 x 1 m up to 4 x 5 m in size. With distance seaward, the deep boundary of the limestone blocks increased; 11 m at FK-4, 12 m at FK-5, and 13 m at FK-6 and 7. The channel wall and limestone blocks provide habitat for fishes, invertebrates and in some localities, resting sites for green sea turtles (*Chelonia mydas*) and are considered to form a distinctive zone or biotope (the biotope of limestone blocks). In general, the development of marine communities is greater in the limestone block habitat at more seaward localities than at more shoreward sites. Below the depth of the blocks, (i.e. down the channel slope) is a second distinctive biotope, the sand-talus slope biotope. The biota of each of these biotopes is described below.

b. The Limestone Block Biotope

The limestone block biotope is generally quite narrow and parallels the Pearl Harbor Entrance Channel. The width of this biotope ranges from about 5 m to 35 m; on the average, the width is about 15 m. The relatively large amount of shelter afforded by these blocks has resulted in the development of a diverse fish community which in turn attracts fishermen to the area. For example, on Sunday 20 September 1998 over a period of two hours, there were six small boats with fishermen and divers using the eastern channel area. One boat was net fishing in the limestone block biotope, having laid a net parallel to the channel wall and the others were spearfishing or line fishing.

In general, the algae are not well-represented in the limestone block biotope. This may be related to the number of grazing fish and invertebrates present. Algal species seen include *Acanthopthora spicifera, Porolithon onkodes, Sporolithon erythraeum* and *Hydrolithon reinboldii*. Estimated coverage by these macrothalloid algae does not exceed 1.5%. Corals are abundant on the limestone blocks. Species of corals seen include *Porites lobata, P. compressa, Pocillopora meandrina, Pavona varians, P. duerdeni, Montipora verrucosa, M. patula, M. verrilli, Psammocora stellata, Fungia scutaria* and *Leptastrea purpurea*.

Over an area of 20 m^2; coverage of corals was measured 26% at FK-4, 22% at FK-5, 19% at FK-6, and 22% at FK-7. Sponges seen include the red sponge (*Spirastrella coccinea*), grey sponge (*Plakortis simplex*) and the black sponge (*Chondrosia chucalla*), but coverage by these species is less than 1%.

Diurnally exposed macroinvertebrates seen in the limestone block biotope include several spiny lobsters or 'ula (*Panulirus marginatus*), slipper lobster or 'ula papa (*Paribaccus antarcticus*), banded shrimp (*Stenopus hispidus*), red swimming crab (*Charybdis erythrodactyla*), shrimp (*Saron marmoratus*), mantis shrimp (*Gonodactylus falcatus*), cone shells (*Conus leopardus, C. ebreus, C. lividus, C. miles*), the auger (*Terebra maculatus*), boring bivalve (*Lithophaga* sp.), pinna (*Streptopinna saccata*), pearl oyster (*Pinctada maragaritifera*), rock oyster (*Spondylus tenebrosus*), polychaete (*Loimia medusa*), christmas tree worm (*Spirobranchus giganteus*), featherduster worm (*Sabellastarte sanctijosephi*), brown sea cucumber (*Actinopyge maurtiana*), black sea cucumber (*Holothuria atra*), black sea urchin (*Tripneustes gratilla*), green urchin (*Echinometra mathaei*), wana (*Echinothrix diadema*), banded urchin (*Echinothrix calamaris*), and slate pencil urchin (*Heterocentrotus mammillatus*). Undoubtedly, there are many other macroinvertebrates that are present but are more cryptic in habits thus were not seen.

Fishes are very common in the limestone block biotope. Rough estimates of biomass suggest that standing crops may locally be as high as 300 g/m^2; standing crops in most natural reef areas do not usually exceed 200-250 g/m^2. Commercially important fishes seen in the biotope of limestone blocks include the weke (*Mulloides flavolineatus*), moano (*Parupeneus multifasciatus*), kumu (*Parupeneus porphyreus*), menpachi (*Myripristes amaneus*), aweoweo (*Priacanthus cruentatus*), malu (*Parupeneus pleurostigma*), ta'ape (*Lutjanus kasmira*), to'au (*Lutjanus fulvus*), a'awa (*Bodianus bilunulatus*), uhu uliuli (*Scarus perspicillatus*), palukaluka (*Scarus rubroviolaceus*), and occasionally one encounters wandering schools of opelu (*Decapterus macarellus*) and solitary papio (*Caranx melampygus* and/or *C. orthogrammus*). Other species of fishes seen include the puhi paka (*Gymnothorax flavimarginatus*), puhi laumilo (*G. undulatus*), nunu (*Aulostomus chinensis*), ala'ihi (*Adioryx xantherythrus*), upapalu (*Apogon kallopterus*), piliko'a (*Paracirrhites arcatus* and *Cirrhitops fasciatus*), juvenile mu (*Monotaxis grandoculis*), kikakapu (*Chaetodon auriga, C. lunula, C. ornatissimus, C. multicinctus*), lau wiliwili (*Chaetodon miliaris*), lau wiliwili

nukunuku'oi'oi (*Forcipiger flavissimus*), angelfish (*Centropyge potteri*), kupipi (*Abidefduf sordidus*), mamo (*Abudefduf abdominalis*), alo'ilo'i (*Dascyllus albisella*), damselfishes (*Stegastes fasciolatus, Chromis hanui, C. ovalis, C. vanderbilti, C. agilis*), wrasses (*Laborides phthirophagus, Pseudocheilinus octotaenia, Pseudojuloides cerasinus*), hinalea aki'lolo (*Coris gaimard*), hinalea lauwili (*Thalassoma duperrey*), 'ohua (*Haliochoeres ornatissimus*), 'omaka (*Stethojulis balteata*), ponuhunuhu (*Calatomus carolinus*), uhu (*Scarus sordidus* and *S. psittacus*), kihikihi (*Zanclus cornutus*), manini (*Acanthurus triostegus*), na'ena'e (*A. olivaceus*), maikoiko (*A. leucopareius*), palani (*A. dussumieri*), pualo (*A. blochii*), ma'i'i'i (*A. nigrofuscus*), maiko (*A. nigroris*), kole (*Ctenochaetus strigosus*), lau'ipala (*Zebrasoma flavescens*), umaumalei (*Naso lituratus*), kala (*N. unicornis*), kala holo (*N. hexacanthus*), 'o'ili (*Cantherhines dumerili*), humuhumu lei (*Sufflamen bursa*), humuhumu mimi (*S. fraenatus*), mo'a (*Ostracion meleagris*), sharpback puffers (*Canthigaster jactator, C. coronata, C. rivulata*), and kokala (*Diodon hystrix*).

Green sea turtles (*Chelonia mydas*) are commonly encountered at several sites along the entrance channel where the limestone blocks are more concentrated creating adequate resting habitat. One approximate 10 x 30m area close to station FK-6, six turtles ranging from an estimated 45 to 80 cm in straight-line carapace length were seen in August 1998. Casual observations along the eastern side of the channel suggest that probably 12 to 20 turtles are using resting habitat in the limestone block biotope at any particular time. In general, these turtles have not been particularly concerned when approached by divers and the usual vessel traffic that plies through the area appears not to present any problem to these animals.

c. The Sand-Talus Slope Biotope

As noted above, a sand-talus slopes is sandwiched between the region of limestone blocks and the sand floor of the entrance channel. Like the limestone blocks, the sand-talus slope biotope is narrow and occurs along the eastern side through most of the outer channel (from FK-4 seaward). The width of this biotope varies from about 10 to 30 m and much of it the substratum slopes towards the channel floor at a 3 to 10° slope. The major colonizer of the area was the seagrass, *Halophila ovalis* present in patches covering from 8 to about 30 m^2 on the sand at depths from 7 to about 12 m.

The biota of the sand-talus slope biotope is not well-developed, and few diurnally exposed invertebrates or fishes were present. The only invertebrate species seen include the auger shells (*Terebra inconstans* and *T. penicillata*), box crab (*Calappa calappa*), and a brown sea cucumber (*Bohadschia tenuissima*) in the sand. On the rubble and hard substratum were seen the sponges *Microciona maunaloa*, *Spirostrella coccinea* and *Chondrosia chucalla* and again, coverage by these species was low.

A number of fishes were encountered in the sand-talus slope biotope. These include the tilefish or maka'a (*Malacanthus brevirostris*), the lizardfish or 'ulae (*Saurida flamma*), the malu (*Parupeneus pleurostigma*) and in one of the August surveys we encountered a small school of opelu (*Decapterus macarellus*) traveling over the sand towards the harbor. Fishes are more common around the small amount of hard substratum present in this biotope. Species seen include alo'ilo'i (*Dascyllus ablisella*), ma'i'i'i (*Acanthurus nigrofuscus*), na'ena'e (*A. olivaceus*), piliko'a (*Paracirrhites arcatus*), and the smalltail wrasse (*Pseudojuloides cerasinus*). Because the biotope of limestone blocks is in very close proximity to the sand-talus slope biotope and many fishes inhabit the area, one often encounters individual fishes wandering out over the sand and rubble foraging for food.

6. END OF CHANNEL TO SAND ZONE (FK-8)

At the seaward terminus of the Pearl Harbor Entrance Channel, the bottom becomes a flat, gently sloping plain between the depths of 20 m and 23 m. Bottom composition in this region, labeled FK-8 consists primarily of sand covered with limestone rubble fragments. Interspersed on the sand-rubble plain are small "patch reefs" consisting primarily of lobate colonies of the coral *Porites lobata* growing on the sand bottom. Other corals present were *P. compressa, Pocillopora meandrina, Montipora verrucosa*, and *M. patula*. The patch reefs were spaced approximately 25 m apart and ranged in size from 1-3 m on diameter. Within each patch reef, living cover comprised 20-30% of the bottom, with the remainder of the reef consisting of the limestone skeletal remains of coral colonies. The other common group of macroinvertebrates in the region were sea urchins, primarily the species *Echinothrix diadema* and *Tripneustes gratilla*. These urchins were common on both the sand-rubble bottom and on the

limestone surfaces of the patch reefs. Fish communities in the area were similar in composition to the limestone block biotope described above.

The composition of the FK-8 area is typical of the depth range along the majority of the southern coastline of Oahu (Mamala Bay), as observed during other studies by the authors. Hence, it does not appear that the region of the proposed outfall alignment represents any unusual or unique habitats.

7. DIFFUSER AREA - SAND ZONE

Beyond a depth of 23 m along the outfall alignment to the depth of the diffuser (26-38 m), bottom substratum consists of a plain of grey calcareous sand. Interspersed on the sand are blocks of limestone rubble. Surveys of the alignment revealed no coral cover in this area. Fish communiites were also limited to lone individuals, presumably as a result of the lack of shelter in the area.

8. SYNOPSIS OF IMPACTS WITH THE PROPOSED PIPELINE ALIGNMENT AND RECOMMENDATIONS

From a biological perspective there are relatively few resources present in the proposed pipeline alignment. Most of the reef flat consists of very low living coral coverage, and there is substantial evidence that the region is subjected to episodic catastrophic natural events which limit reef development. However, there are two areas where the resources are either relatively well-developed or have protected species present. In order to minimize the possibility of disturbance to these resources, several alternate routes were investigated. The first area is on the reef flat where the *Porites spp.* microatolls are located. These microatolls only form on shallow reef flats where wave disturbance is minimal and conditions for coral growth are appropriate. They are not a common element on Oahu reefs.

In order to establish the potential for avoiding impacts to the microatoll zone, the landward (easterly) extent of the zone was determined during follow-up surveys. It was determined that the microatoll zone ends approximately 50 m to the east of the original proposed alignment. Thus, the area could be avoided by re-routing the discharge pipe alignment about 50 m to the east of the present proposed during the construction process (i.e., trenching, pipe deployment and backfilling) much of the silt generated during the process would be contained. It should also be noted that during surveys of the reef flat, conditions often consisted of extremely turbid water. Hence, it can be concluded that existing flora and fauna are tolerant of high turbidities that occur in the natural state.

The second area where potential impacts to coral communities may be substantial with the originally proposed routing is along the channel wall seaward of the breakthrough from the microtunnel. As noted above, the limestone block biotope along the eastern side of the entrance channel has a relatively good development of corals and the fish community is diverse. The area serves as resting habitat for green sea turtles which are a threatened species protected under federal law. The originally proposed pipeline alignment traverses the long axis of the limestone block biotope which would impact coral and fish habitat. To avoid these adverse impacts, the pipeline alignment could be moved westward to the middle of the sand-talus slope zone, thereby avoiding the limestone block biotope. These two proposed changes should minimize or the eliminate the possibility of impact to these marine communities.

Surveys revealed small percentages of living coral in the area of the jacking shaft and barge access channel. Extrapolation of transect data indicates that approximately 2% of the area consists of live coral. This percentage equates to a coverage of approximately 30 m^2. Most of the corals in this area were small colonies that could be relatively easily moved to other locations and re-attached to the bottom. Such transplantation of corals has been performed at other construction sites in Hawaii with good success, resulting in no net loss of living corals.

While corals exist in the region between the end of the entrance channel and the sand zone, this area is part of a large habitat that stretches along the entire southern shoreline of Oahu. At depths below the rubble zone where the diffuser will be located, bottom composition consists of sand with no coral cover.

The final area that was surveyed was the strip of reef flat proposed as a truck corridor extending from a shoreline access road directly east of the outfall line at FK-1 to the outfall alignment in the vicinity of FK-1. This area consisted of algal covered sand/rubble flats with no corals present.

Appendix IX

Ocean Activities Survey for the Outfall Replacement: Wastewater Treatment Plant at Fort Kamehameha

OCEAN ACTIVITIES SURVEY

for the

Outfall Replacement: Wastewater Treatment Plant
at
Fort Kamehameha

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1.0 OCEAN ACTIVITIES SURVEY

1.1 Purpose.

This ocean activities survey was undertaken to provide background information for an environmental impact statement (EIS) for the Outfall Replacement: Wastewater Treatment Plant at Fort Kamehameha, Pearl Harbor, Hawaii. The information is intended to assist Sea Engineering, Inc. and Belt Collins Hawaii in addressing environmental and social concerns regarding the construction of a new 3500 to 4000 meter (11,500-12,900 foot) long, 1050 mm (42 inch) diameter, high density polyethylene (HDPE) outfall terminating at a water depth of approximately 37 meters (120 feet). The outfall will terminate with a reinforced concrete pipe (RCP) diffuser approximately 460 meters (1500 feet) long. The existing outfall will remain for emergency operations.

1.2 Scope.

The scope of work included:

1. Observing ocean activities and ocean conditions at Hickam Harbor and Fort Kamehameha and in neighboring shoreline areas.
2. Interviewing resident and military shoreline users, including lifeguards and fire fighters who provide emergency rescue services.
3. Identifying the potential impacts of the outfall on ocean activities.
4. Assisting other consultants with environmental and social concerns related to ocean activities.

1.3 Survey Methodology.

Information for this survey was gathered from site visits and from interviews with people familiar with Hickam Harbor and Fort Kamehameha and neighboring shoreline areas. Site visits and interviews were conducted during October, November and December 1996. Additional information was gathered from the references that are listed in the References section.

2.0 PHYSICAL CONDITIONS.

2.1 Survey Area.

The survey area is the shoreline of Hickam Air Force Base (AFB) situated between the west end of the Reef Runway complex and the Pearl Harbor Channel. It includes the Hickam Outdoor Recreational Facility, the Hickam

Wetland Management Area, Fort Kamehameha housing, and the ocean approximately one mile offshore.

The survey area lies within West Mamala Bay which is the shoreline from the Reef Runway to Barbers Point. This shoreline is primarily artificial, the result of extensive dredging of reef areas, the construction of artificial structures, and the filling of former mudflats, fishponds, and shallow reefs. In spite of the alterations and artificial structures, the shoreline of the survey area still provides many opportunities for ocean activities, especially swimming, fishing (including seaweed gathering) and boating.

Currents. The survey area is located primarily in the lee of the Reef Runway complex, a generally current-free site. Occasionally, wind driven surface currents are evident as are tidal currents, but both are normally negligible and do not pose a threat to ocean activity user groups.

Surf breaking on the outer reefs generates rip currents along both edges of the Hickam Harbor Channel. The rip currents are of short duration and normally terminate just beyond the surfline. Although some of them reoccur in the same places, they migrate, depending on the size and direction of the surf and the level of the tide.

Surf. No surf normally breaks onshore in the survey area. Small waves averaging from 1-2' in height may occur during severe tropical storms (winds of 35 to 64 knots) and hurricanes (winds of 65 knots or greater), but surf from these sources is infrequent. Surf, however, does occur offshore on Ahua Reef on both sides of Hickam Harbor Channel. The surfing break on the east side of the channel is called Firsts, and the surfing break on the west side of the channel is called Seconds. Both sites occasionally experience waves heights up to 10 feet during both summer and winter high surf conditions, but these surfing sites are located so far offshore that high surf wave energy from them is almost entirely dissipated in the harbor before it comes ashore.

Regional Winds. In Hawaiian waters strong, gusty trade winds blow from a northeasterly direction and prevail throughout most of the year. During the summer months from June through August, the trade winds prevail over 90 percent of the time and have direct impacts on local beach sites. In the survey area the trade winds blow offshore toward Pearl Harbor Channel.

Interruption of the normal trade winds often results in southerly or Kona winds that are usually light and variable. Kona winds are more common during the winter months, but may occur at any time of year. They blow directly onshore in the survey area and produce rough, choppy ocean conditions.

Lifeguards. The lifeguards at the Hickam Harbor beach parks are civilians who are hired by the Department of the Air Force. The staff consists of eight lifeguards who guard the beach every day of the year. Additional lifeguards are hired during the busier summer months.

There are two towers on the beaches, one at Honeymoon Beach and one at Hickam Beach. In the event of a nearshore rescue incident, the lifeguards can use a rescue tube or a rescue surfboard to assist a victim. In the event of an incident further offshore such as in the surfing areas or beyond, the lifeguards have the use of a power boat at the small boat harbor.

Rescue incidents have included assisting children and adults who are poor swimmers who have been unable to return to shore and assisting boats in distress offshore. Wind is a problem for novice kayakers and windsurfers.

Rescue incidents have also included first aid for Portuguese man o' war stings.

Lifeguards use Buoy #5 as a turn buoy for rescue surfboard training. They estimate that from shore to the buoy and back is a one mile paddling course.

Jellyfish. Jellyfish such as the Portuguese man o' war, a floating marine jellyfish that can deliver a painful sting, are found infrequently in the survey area, usually during periods of strong southerly winds. Bell-shaped jellyfish appear occasionally during normal wind conditions and seem to congregate near the revetment of the Reef Runway. They also sting, but not as severely as other jellyfish.

Sharks. Sharks are common in Hawaiian waters, but usually do not pose a threat to swimmers. They are well fed by the abundance of reef and pelagic fish. Sharks appear regularly in the nearshore waters fronting Hickam AFB, especially juvenile hammerhead sharks 1-2' long. They are occasionally seen nearshore by swimmers and are often caught by fishermen, especially during the summer months when they seem to congregate in the harbor. Adult hammerheads are not seen or caught in the same area. Juvenile black tip sharks are also seen regularly on the Reef Flat.

Larger sharks are commonly seen in both the harbor channels, particularly the Pearl Harbor Channel, and occasionally on the reef flat at high tide. A variety of sharks, including tigers, grays, black tips, white tips and Galapagos, have been seen.

Sharks, including tiger sharks, feed on green sea turtles. The abundance of turtles feeding at Ahua Reef may contribute to attracting sharks nearshore.

According to one net fisherman, during the past two years reef sharks have been increasing in numbers and getting more aggressive in the survey area. In the past they stayed in the distance, but now when fish are caught in their nets, the sharks attack the nets. Sharks also come around if they or anyone else is spearing octopus. If they see octopus near their nets, they do not spear them until they are finished with the fish. In addition, they do not surround fish if other divers are in the area are spearing octopus.

To date, there have been no shark attacks in survey area.

Unexploded Ordinance. Unexploded ordinance in the form of cannon projectiles is found on the ocean floor offshore the Reef Runway. It is probably from the World War II period when Fort Kamehameha was an Army installation that was fortified with shoreline artillery. The weapons were probably fired for practice. No projectiles have been observed in the Pearl Harbor Channel area.

2.2 Hickam Outdoor Recreational Facility

The Hickam Outdoor Recreational Facility is located on the shoreline of Hickam AFB. It is situated between the Reef Runway of the Honolulu International Airport and Fort Kamehameha and includes two beach parks, Honeymoon Beach Park and Hickam Beach Park, the Sea Breeze Restaurant, and Hickam Harbor, a small boat harbor.

2.21. Honeymoon Beach Park. Honeymoon Beach Park is located on the shoreline of Hickam AFB where the Reef Runway taxiway intersects the shoreline. The park includes a small, artificial, calcareous sand beach approximately 150 feet long by 75 feet wide, portable toilets and a lifeguard tower. Use of the beach and its facilities is by permit only. Permits are issued by the Hickam Harbor operations office, primarily to organized groups.

Ocean recreation activities at the beach include sunbathing and swimming and occasionally windsurfing. Fishing is permitted from the rocks of the Reef Runway taxiway, but not at the beach.

2.22 Hickam Beach Park. Hickam Beach Park is located on the shoreline of Hickam AFB between the mouth of Kumumau Canal and the seawall fronting the Sea Breeze Restaurant. The park includes a small, artificial, calcareous sand beach approximately 500 feet long by 75 feet wide that was created in 1968 with the assistance of Marine Corps explosive ordinance detail personnel. Facilities include a beach bathhouse, a lifeguard tower, picnic cabanas and an equipment rental concession.

Nearshore ocean activities include sunbathing and swimming. Although some swimmers attempt to snorkel in the swimming area, underwater visibility is very poor and not conducive for snorkeling or scuba diving. The poor visibility is a normal condition that results from the constant suspension of silt from the harbor bottom. During periods of heavy rains, mud plumes from Kumumau Canal at the east end of the beach form in the harbor, further impacting the visibility as well as the swimming conditions. A designated swimming area fronting the beach is marked by six permanent buoys. Swimmers are restricted to the area inshore of the buoys to prevent interaction between them and the power and sail boat traffic offshore.

Offshore the swimming area is a waterski ramp and a mooring area for approximately 15 boats. Offshore ocean activities include kayaking, outrigger canoe paddling, peddle boating, windsurfing, sailing, waterskiing, and boating. At the east end of the designated swimming area, a small channel adjacent to the rubblemound groin separates the beach from Kumumau Canal. This channel

starts at the beach and ends in the harbor and is intended to separate the swimmers from the ocean recreation equipment users such as kayakers, outrigger canoe paddlers, peddle boaters and windsurfers. The channel also provides the equipment users with a site to launch and land.

2.23 Hickam Harbor.

During the early 1940's a series of seaplane runways were dredged in Keehi Lagoon. Part of this project included dredging one runway parallel to the shoreline from Ahua Point to Fort Kamehameha. Today, the remnants of that seaplane runway are the Reef Runway Lagoon, an approximately 200-acre, sand-bottomed, brackish lagoon which is enclosed by the Reef Runway complex, and the harbor at Hickam Harbor. The Hickam Harbor complex was built at the west end of the former seaplane runway.

Prior to the construction of the Reef Runway in the 1970s, boaters from Hickam Harbor reached the open ocean by using the former seaplane runway to reach Kalihi Channel in Honolulu Harbor. This access was blocked when the construction of the Reef Runway filled in most of the seaplane runway and a large portion of Ahua Reef. The present Hickam Harbor Channel to the west of the Reef Runway was dredged through Ahua Reef to give boaters access to Hickam Harbor. It was part of the Reef Runway construction.

The small boat harbor at Hickam Harbor includes 16 slips for power or sail boats up to 26 feet long, a fueling station with a 1000 gallon fuel tank, a single lane, concrete launch ramp, a boat washdown area, a paved storage lot for 60 trailered boats, a harbor operations office building, a boat maintenance building, a hoist for boats up to 4,000 pounds, and 15 offshore moorings. Use of the harbor and its facilities is limited to military or Department of Defense personnel and their dependents.

2.3 Hickam Wetland Management Area.

The Hickam Wetland Management Area is located on the shoreline of Hickam AFB between Hickam Harbor and Fort Kamehameha housing. It is opposite the Hawaii Air National Guard facilities. Approximately 60 percent of the wetland consists of a dense growth of mangrove trees, ranging in height from 6 to 12 feet. On slightly higher ground, a large patch of pickleweed comprises the remaining 40 percent of the vegetative cover. Mangrove and pickleweed are salt-tolerant species. The wetland is adjacent to the ocean and is subject to daily tidal inundation. It was once part of the Ahua Reef reef flat that was filled by the U.S. Army many years ago to form the foundation for Fort Kamehameha. Several small pocket beaches of calcareous sand are located on the east side of the mangrove trees where the ocean is eroding the coral fill.

The wetland has been interpreted by the Environmental Section at Hickam AFB and designated as a management area. Informational kiosks with signs describing the wetland's flora and fauna have been placed at both ends of the area. The kiosks include maps of the trails through the wetland and points of

interest along the trails. The signs also describe the reef flat offshore and some of its inhabitants.

Recreational uses of the wetland are passive and restricted to pedestrians hiking on the trails. An unpaved, open lot west of the wetland and adjacent to the informational kiosk is used as a parking lot and an access point for the reef flat offshore, but vehicles are not permitted in the wetland area proper. Fishing is not permitted there either, but is permitted along the seaward edge of the Hawaii Air National Guard parking lot to the east. Fishing is permitted offshore on the reef flat.

2.4 Fort Kamehameha.

Fort Kamehameha is located on the shoreline of Hickam AFB between the Hickam Wetland Management Area and the Pearl Harbor Channel. On the shoreline it consists primarily of a housing complex for field grade officers (majors and above) and the Fort Kamehameha Waste Water Treatment Plant (WWTP). The housing units are fronted by a narrow calcareous sand beach that is experiencing some minor erosion in the backshore. The beach is almost entirely submerged at high tide and is often covered with seaweed at low tide. Ocean activities include swimming at high tide by some of the children in the housing complex, sunbathing, kayaking, fishing, reef walking and sailing.

2.5 Offshore Hickam AFB.

The area offshore Hickam AFB is defined by the Reef Runway complex to the east and the Pearl Harbor Channel to the west. The two prominent features within this area are Hickam Harbor and the western remnant of Ahua Reef. The harbor averages 15 to 20 feet deep and has a mud substrate estimated to be 4 feet deep. Nearshore underwater visibility is extremely poor. Visibility improves offshore near the west end of the Reef Runway where there are several patch reefs in the lee of the runway on the east side of the Hickam Harbor Channel. Several sites in this area are used as occasional day anchorages by boaters from Hickam Harbor, primarily on the weekends.

The western remnant of Ahua Reef lies between Hickam Harbor Channel and Pearl Harbor Channel. It consists of three distinct habitats: a stand of mangrove, an extensive shallow reef flat and a deeper reef slope.

The reef flat is shallow and heavily silted inshore, but as the water depth increases moving in a seaward direction, the bottom composition changes to a mixture of limestone reef, coral rubble and sand. This particular reef flat is very shallow with an average water depth of 0-3', depending on the level of the tide, the difference between normal high and low tides averaging between two to three feet. The reef flat extends out to the large concrete tower on the edge of Pearl Harbor Channel where it drops off to the reef slope. Tidal currents and surf-generated longshore currents have impacted the reef flat by creating two small, vegetated intertidal sand islands immediately offshore Fort Kamehameha housing. Although some patches of reef are found nearshore, well developed

reefs are only found one half mile or more offshore, in line with the Reef Runway. Live corals, invertebrates, crustaceans, gastropods and fish populations are moderately abundant on these reefs and much less abundant nearshore.

The reef flat is rarely subject to wave activity, except during severe southerly storms, but some erosion has occurred on the shoreline in this area. However, there is no evidence of seasonal erosion and accretion of sand. Organic and inorganic debris, especially seaweed, collect on the beach, especially at low tide.

3.0 OCEAN ACTIVITIES.

The shoreline fronting Hickam AFB is a popular ocean activities area. Ocean activities occur between the Reef Runway complex and the Pearl Harbor Channel and are concentrated on the shoreline at the Hickam Outdoor Recreation Facility, at the Hickam Wetland Management Area, and at Fort Kamehameha housing.

Most of the activity is concentrated at Hickam Beach Park. Although the beach area is small and the water there is murky, it is an easily accessible beach for military personnel who live nearby. There are no other beaches in the vicinity that are convenient to Hickam AFB, Pearl Harbor, or any of the nearby military housing areas. The military also provides lifeguard service, ocean recreation equipment rentals, a restaurant, and a food concession, the combination of which has made Hickam Harbor especially attractive to military families with children.

Offshore ocean activities are concentrated on Ahua Reef, either on the reef flat or on the reef slope. The military has jurisdiction of the waters out to the end of the Reef Runway, so the entrance channel and harbor of Hickam Harbor are restricted to boats owned and operated by military or Department of Defense personnel. Boats owned and operated by the public are not permitted inshore of the Reef Runway. From the Reef Runway seaward boaters and other ocean activities user groups include military personnel; Department of Defense civilian personnel and the general public.

Some of the fishermen on the Reef Runway are civilians who walk or ride bicycles around the Reef Runway security fence from Lagoon Drive, following a path that was provided for public access. Civilians who are not Department of Defense personnel also fish on Hickam AFB if they have a current fishing pass. Annual fishing passes are issued upon request from the Visitors Office at the main gate. The passes allow fishing only on weekdays and only on the Reef Flat fronting the Hickam Wetland Management Area.

3.1 Specific Activities.

3.10 <u>Beachcombing</u>.

Beachcombing in the traditional sense of walking along a sand beach and combing through the marine debris for any matter of personal value is an infrequent activity in the survey area. Except for seaweed, very little marine debris washes ashore. Some beachcombing for shells takes place on the two sand islets offshore Fort Kamehameha housing and on the Reef Flat during low tides, and walking the shoreline trails in the Hickam Wetland Management Area is encouraged as an educational experience. The number of users averages approximately 2 per day on weekdays, and 6 per day on weekends and holidays.

3.11 Fishing.

Fishing is a popular activity that takes many forms in the survey area, including fishing from boats and from shore. A number of free swimming and schooling species are found nearshore, including papio, moi, oio, awa and mullet, and many common reef species are found offshore on Ahua Reef.

• Gathering. During periods of calm seas, opihi are picked from the seaward side of the Reef Runway, but this is an infrequent activity because the resource is so limited. The number of users averages approximately 2 per day on weekdays and 4 per day on weekends and holidays.

Gathering activities take place most frequently on the Reef Flat fronting Fort Kamehameha and from a small patch reef offshore the missile storage site between Honeymoon and Hickam Beaches. Gathered species include seaweed, primarily ogo and manauea. The number of users depends on the day of the week and the level of the tide. The most heavily used days are Saturdays, Sundays and holidays during daylight hours when the tide is at its lowest. The number of users averages approximately 20 per day on weekdays and 70 per day on weekends and holidays.

Seaweed gathering is limited to one pound per person per day. DLNR personnel occasionally police the Reef Flat to insure that pickers are in compliance. They are an infrequent user group.

Lobsters are gathered by hand all across Ahua Reef, especially by divers near the outer channel markers. The number of users averages approximately 2 per day on weekdays and 10 per day on weekends and holidays.

• Netting. Some gill net fishing occurs for fish occurs on both sides of Hickam Harbor Channel, and some thrownet fishing occurs along the Reef Runway revetment, especially for mullet which occasionally school through the area. Some thrownet fishing for mullet and oio is done on the Reef Flat. The number of thrownet fishermen averages approximately 2 per day on weekdays and 4 per day on weekends and holidays.

The majority of the net fishing in the survey area is done offshore by commercial fishermen. Commercial surround net fishing operations take place to catch migrating schooling fish such as akule and sometimes ulua. Normally, commercial fishermen have several boats and a spotter plane to locate the schools of fish. When the pilot spots a school, he radios the school's location to

the boats below. Directed by the pilot, the boats circle the school, dropping their large fence and bag nets as they go. They fish from Barber's Point to Makapuu Point, depending on the weather and surf conditions and where they fished last. However, these large scale fishing operations occur infrequently in the survey area because of the restrictions on flying in the airspace fronting Hickam AFB and Honolulu International Airport. In addition to the commercial net fishermen, other smaller groups of fence and bag net fishermen who do not use airplanes for spotting also visit the area. The number of commercial fishing boats averages approximately 3 per day on weekdays and 6 per day on weekends and holidays.

Commercial underwater surround net fishing operations are more common in the survey area. Instead of using surround nets on the surface, these fishermen use scuba gear to set up surround nets underwater into which they herd reef schooling fish such as weke, mu, kumu and tape. These commercial operations occur in waters from 40 - 100 feet. In addition to fishermen from the Honolulu area, the survey area and certain areas offshore Ewa Beach to the west attract fishermen from the North Shore. They come during the winter months when high surf on the North Shore precludes underwater surround net operations there. The number of commercial fishing boats averages approximately 3 per day on weekdays and 6 per day on weekends and holidays.

Crab netting takes place infrequently near the canal mouths and bridges for bottom dwelling crabs such as Samoan crabs. The survey area's nearshore waters are considered to be poor crabbing areas. The Reef Runway is noted for its large populations of aama crabs, a popular luau dish. Kona crabs are not caught in the survey area, but further to the west offshore Ewa Beach in waters from 20-50 fathoms deep. Crab fishermen are an infrequent user group.

• Pole Fishing. Pole fishing is prohibited along the shoreline of the survey area, except for the paved parking lot across from the Hawaii Air National Guard facilities. Beyond the shoreline, pole fishing, especially whipping, occurs along the revetment that comprises the western edge of the Reef Runway and along the edges of the reef flat in Hickam Harbor and in the Pearl Harbor Channel, especially at low tide. Other pole fishermen such as shore casters fishing for ulua are found at the westernmost point of the Reef Runway, especially on weekends when they may fish throughout the night. Some pole fishing for oama occurs on the reef flat during the summer months when these juvenile goat fish school in shallow, sandy areas around the island. The number of pole fishermen averages approximately 2 per day on weekdays and 4 per day on weekends and holidays.

Some pole fishing occurs from boats offshore.

Some catamaran sailors and kayak paddlers attach fishing poles or handlines to their crafts and troll for papio and other species as they transit the area.

Commercial and recreational handline fishing for akule and opelu occurs at night at certain times of the year when these fish are schooling. Boats usually anchor near Buoy #1. This is an infrequent activity that only occurs when the fish are schooling in that area. At those times, as many as 15- 20 boats may be fishing.

• Spear fishing. Spear fishing by both commercial and recreational fishermen occurs primarily in the deeper waters near the Reef Runway. Spear fishing occurs from boats for all fish species and octopus, especially in the area of Buoys #1 and #2, the outermost buoys of the Pearl Harbor Channel. Water depths average 60 feet. The number of boat with fishermen averages approximately 2 per day on weekdays and 15 per day on weekends and holidays.

The ocean bottom beyond the reef slope is generally regarded as marginally productive for reef fish. With few exceptions the bottom is typically a featureless, limestone plain that offers little relief and therefore shelter for large numbers of reef fish. While these areas do not attract many varieties of fish, they often provide good habitat for octopus or "squid" as most local fishermen call them. Squidding occurs offshore the entire survey area. Spear fishermen skin and scuba dive inside the Reef Runway on several patch reefs in the Firsts area and on Ahua Reef across the Hickam Harbor Channel in the Seconds area. Almost all of the offshore areas are accessed by boats launched either from Hickam Harbor or from Keehi Lagoon, the location of the nearest public launching ramp.

During periods of calm seas, some night scuba diving occurs by members of the Sea Lancers Dive Club. These dives are usually for non-consumptive activities.

Some torch fishing occurs on the reef flat, normally on dark, moonless nights, for night octopus and reef fish such as weke and kumu. This is an infrequent activity.

• Trapping. The majority of the trapping in the project area is done by a commercial trap fisherman who has been trapping there for the past ten years. He usually sets ten traps at depths from 80' to 100', including traps in the area where the outfall is projected to terminate. He catches and sells all varieties of reef fish such as pualu and palani. He does not trap for lobster. Other trap fishermen fish are to the east and west of him. They all have a gentlemen's agreement to stay out of each other's areas.

• Tropical fish collecting. Several commercial tropical fish collectors operate regularly in the area. They come in by boat from Keehi Lagoon and scuba dive on the reef slope at depths of 40- 60 feet. They sell their fish to aquarium fish wholesalers. The number of tropical fish collectors averages approximately 2 per day on weekdays and 2 per day on weekends and holidays.

3.12 Kayaking. Ocean kayaking is a popular activity in Hickam Harbor. The equipment rental center rents polyurethane kayaks. Lifeguards advise inexperienced kayakers to remain close to shore rather than attempting to reach the Reef Runway or cross the Pearl Harbor Channel.

The waters fronting Hickam AFB are a transit area for kayakers who have launched their crafts from other areas. During the spring and summer months long distance kayak are held on Oahu and the race courses for several of these races pass through the waters offshore.

3.13 Outrigger Canoe Paddling. Outrigger canoe paddling is Hawaii's official ocean team sport, and annually attracts approximately 10,000 participants state-wide. The short course regatta season begins in the spring and ends with the state championships in August. Then the long distance racing season begins and ends with the Molokai-to-Oahu race in October. While none of Oahu's canoe clubs train in the survey area, Keehi Lagoon Park to the east is one of the premier racing sites on the island. The 72-acre park has a Canoe Facility (a viewing and judging stand) and a small artificial beach for launching and landing canoes during regattas. Outrigger canoes transit the offshore waters of the survey area, either in training or during long distance races. In addition to these regattas, there are approximately 10 long distance races that are held in the area by OHCRA, Hui Wa'a, as well as high school and women's groups. They transit the area.

Hickam Harbor also has two outrigger canoes available as rentals. These canoes are normally used within the confines of the harbor and not beyond the Reef Runway.

3.14 Power Boating. Power boats are permitted in all areas of the harbor except in the zones set aside for swimmers only. Some boaters use the cove inside the west end of the Reef Runway as a day anchorage to dive on the patch reefs there or as a picnic site for their boats. The number of boats averages approximately 1 per day on weekdays and 3 per day on weekends and holidays.

3.15 Reef Walking.

Reef walking is a popular activity on the reef flat. Some individuals and families go on their own, but most of the reef walks are organized and conducted by an experienced leader. During Christmas, spring and summers vacations, the Hickam Outdoor Recreational Facility office coordinates reef walks, primarily for dependent children. They go at low tide with view boxes. Commonly seen fish include small snowflake moray eels, conger eels and puffers. The number of reef walkers averages approximately 2 per day on weekdays and 6 per day on weekends and holidays. Guided reef walking tours are conducted approximately 6 times per year and may include as many as 50 students.

The reef flat is recognized by the Department of Education as an educational reef walking site and is listed in its manual A Compendium of Coastal Field Sites. School classes continue to use the site.

In the 1970's the reef flat was used to conduct a research study on the contributions to sediment stability by marine invertebrates. The study identified two populations of invertebrates. The reef flat is still used for invertebrate studies by the University of Hawaii Zoology Department. It is considered a unique south shore reef and an excellent area for reef walking because comparatively, it has

so few users. Reef walking for marine invertebrate studies is an infrequent activity.

3.16 Scuba Diving.
Scuba diving is conducted primarily by the members of the Sea Lancers Dive Club, a military dive club that was formed in 1958. The club is still active and its members dive regularly offshore on both sides of the Pearl Harbor Channel. Club members also assist the Hickam Harbor staff with the installation and maintenance of various buoys in the harbor. Club dives are made almost exclusively from boats. The number of club divers averages approximately 50 per dive, and dives are usually limited to 2 per day on weekends and holidays.

Some scuba diving by individuals occurs from shore. These divers park at the west end of the Hickam Wetland Management Area, then walk across the reef flat to the drop off (approximately where the concrete observation tower is located at the edge of Pearl Harbor Channel). This is an infrequent activity.

3.17 Shelling.
Ahua Reef is an important shell collecting reef, especially for cowries and cones. In the shallows snake head cowries, Cypraea caputserpentis, are found under rocks. A rare and endemic cowry, the checkered cowry, Cypraea tessallata, is found near the drop off. Simi-plota or half-swimmer cowry is also found near the drop off. Shell collectors consider it to be a rare shell. Textile, Hebrew and abbreviated cones are commonly found at all depths. Tiger cowries and reticulated cowries are found at the drop off into Pearl Harbor Channel.

Ahua Reef is an excellent shell reef. Some shell collectors consider it to be one of the last if not the last good shelling reef on Oahu. Other areas around the island are all easily accessible and heavily dived. Access to Ahua Reef is limited to boats for most civilians and is used by only a limited number of military personnel. The number of shell collectors cannot be determined. Shell collecting is usually a secondary activity that occurs in conjunction with primary activities such as reef walking, spear fishing, scuba diving and so on.

Many of the shells in the Bishops Museum's marine mollusk collections are from this reef.

At certain times of the year, usually September and October, sea urchins congregate on the ocean bottom offshore. Helmet shells in large numbers come to feed on them and are collected. This usually occurs near Buoys 1 and 2 in the Pearl Harbor Channel.

3.18 Sailing.
Most beach sailing in Hawaii occurs on small, double-hulled catamarans such as Hobie Cats. These sturdy craft are well suited to contend with the winds and surf in Hawaiian waters and are usually seen sailing on the windward side of Oahu. A few of these small craft are sailed from the beach at Fort Kamehameha. Larger sailboats are moored at Hickam Harbor. Boating activities in the harbor include sailing classes for children and adults.

Sailing classes are conducted by the staff at Hickam Harbor.

Competitive sailing in Honolulu takes three forms: local yacht club races, large scale professional competitive race series based out of Honolulu such as the Kenwood Cup and races in which Honolulu is the final destination such as the Transpac. The Transpac and the Kenwood Cup occur on alternate years. Competitive sailing yachts transit the waters offshore the survey area during certain legs of their races.

3.19 Sunbathing and Swimming.
Sunbathing and swimming are the two most popular activities in the survey area. Sunbathers and swimmers are concentrated primarily at Hickam Beach and secondarily at Honeymoon Beach. Both beaches and their facilities are used almost exclusively by military and Department of Defense personnel and their dependents.

According to daily beach counts kept by the lifeguards, approximately 150- 300 people per hour use Hickam Beach during slow periods, and approximately 300-600 people per hour during peak periods. Slow periods include weekdays, especially during the fall and winter months. Peak periods include weekends and holidays, especially during the spring and summer months. The weekend that includes the Fourth of July holiday is the busiest weekend of the year.

Some swimming occurs at Fort Kamehameha where dependent children occasionally swim at the beach fronting their homes, usually at high tide. Some sunbathing occurs on the two small sand islands offshore the housing.

Some swimming occurs from boats that anchor in the lee of the west end of the Reef Runway.

3.20 Surfing.
Firsts and Seconds are the only two surfing breaks located in the survey area. Firsts is located on the east side of the Hickam Harbor Channel, and Seconds is located on the west side of the channel at Buoy #5. Both sites are approximately one-half mile offshore Hickam Harbor. Both sites offer excellent opportunities for intermediate and advanced surfing. Because of the distance from shore to these sites, they are surfed infrequently. The number of surfers averages approximately 15 per day on weekdays and 15 per day on weekends and holidays when wave conditions are optimal.

No surfing contests take place Hickam Harbor.

3.21 Thrill craft.
The interaction between thrill craft riders and other ocean activity user groups can be dangerous because of the high speed of the thrill craft. For this reason, thrill craft are prohibited in the harbor and restricted to an area offshore the Reef Runway. This area is identified in the Department of Land and Natural

Resources' Hawaii Administrative Rules, Part III Ocean Waters, Navigable Streams and Beaches, Paragraph 13-256-94 Reef Runway Zone F. It states that Reef Runway Zone F is designated for recreational thrill craft operations.

At least one commercial jetskiing rental operation uses Keehi Lagoon. Their base of operations is concentrated on several of the small tidal islands on the west side of Kalihi Channel. Customers are transferred to and from the islands by boat from Keehi Lagoon Boat Harbor. Occasionally, their customers proceed west of Zone F and ride into Hickam Harbor. The lifeguards from the Hickam Beach use their power boat to contact the jet ski riders and escort them out of the area.

3.22 Tour Boats
The Oahu tour boat industry operates between Hawaii Kai and Pearl Harbor. The vessels range from tourist catamarans to 100 foot cruise vessels that offer tourists dinner cruises as well as various excursions. The Pearl Harbor cruise vessels traverse the waters offshore the survey area.

3.23 Waterskiing. Hawaiian waters offer very few opportunities for waterskiing. Two of the primary sites on Oahu are Hickam Harbor, west of the Reef Runway, and Keehi Lagoon, east of the Reef Runway. Both sites utilize former World War II seaplane runways and are probably the most intensively used waterskiing sites in the State. Waterskiing competitions are held at Keehi by the Oahu Waterskiing Association and at Hickam Harbor by the military. Boats for waterskiing and waterskiing equipment rentals are available at the Hickam Harbor recreation office, but most waterskiers come with their own boats and equipment. The number of waterski boats averages approximately 1 per day on weekdays and 3 per day on weekends and holidays.

3.24 Windsurfing.
Normal trade winds and southerly or Kona winds provide adequate conditions for windsurfing. Windsurfers launch at Hickam Harbor, at the east end of Hickam Beach, and on Kona wind days at Honeymoon Beach. Honeymoon Beach is not a good launching site on trade wind days. Windsurfers occasionally jump and surf the waves at Firsts and Seconds, but this activity is not encouraged by the lifeguards because the surfing sites are so far offshore. If windsurfers get in trouble there, they may drift west across Pearl Harbor Channel into the Iroquois Point area before help reaches them. The number of windsurfers averages approximately 3 per day on weekdays and 8 per day on weekends and holidays.

4.0 Impacts on Ocean Activities.

In the Executive Summary Report dated April 10, 1995, Route D is identified as the preferred alternative for the siting of the new outfall. This route would take the outfall on a direct path from the WWTP across the Reef Flat to the east side of the channel approximately 700 feet inshore of buoy R4. From that point the outfall would be buried along the east side of the channel at a depth of 45 feet

and extend seaward to a minimum depth of 120 feet where the diffuser will be located.

Nearshore Impacts. The Reef Flat is one of the most used areas in the project site, and Route D, the preferred alternative, includes a construction phase across the Reef Flat. Short term impacts during this phase would include suspending all ocean activities that take place now on the Reef Flat or limiting them to certain areas of the Reef Flat away from the construction. The margin of safety necessary to protect the Reef Flat user groups from the construction would be determined by the contractor and the Navy, but it would be less disruptive to the user groups if they were allowed at least partial use of the Reef Flat, perhaps from the Hickam Wetland Management Area to the eastern edge of the Reef Flat.

It should be noted that although the Reef Flat is one of the most used areas in the project site, it is not heavily used in comparison with other similar areas in the civilian community such as the reef flats offshore Ewa Beach. This is because the Reef Flat lies within restricted shorewaters and is accessible primarily to military or Department of Defense personnel only. Therefore, during the construction phase, although certain user groups will be inconvenienced, the actual number of people who will be impacted will be small.

Long term effects on ocean activities will be determined by the effects of the construction on the marine life in and around the Reef Flat. Almost all of the activities occurring there, except for reef walking, are consumptive such as seaweed gathering, fishing and shelling. If the construction reduces the seaweed, fish and shell populations, the number of users seeking these resources will decrease.

The proposed construction will not have any impact on the ocean activities that occur within the Hickam Outdoor Recreational Facility adjacent to the Reef Flat, including Hickam Harbor and Hickam and Honeymoon Beaches. However, the reef-walking tours that are conducted by the staff at Hickam Harbor (and by others) will be impacted by whatever decision is made regarding the ocean activities on the Reef Flat during the construction.

Offshore Impacts. Short term impacts during construction may include suspending all ocean activities that take place now on the Reef Slope and in the other areas seaward or limiting them until the outfall is completed. This would include surfing at Seconds, scuba diving, fishing, including trapping and netting, and boating. The margin of safety necessary to protect the user groups from the construction would be determined by the contractor and the Navy.

Long term impacts may include an increase in the marine life along the outfall if it evolves into a marine life aggregation device which in turn would probably increase the number of users, especially boaters, in the area.

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Appendix X

Fort Kamehameha Outfall Extension Dredging Turbidity Investigations

FORT KAMEHAMEHA OUTFALL EXTENSION
DREDGING TURBIDITY INVESTIGATIONS

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1.0 INTRODUCTION

Project Location and General Description

The Navy's Wastewater Treatment Plant at Fort Kamehameha presently discharges through a 540 meter long outfall which terminates in the Pearl Harbor entrance channel (Figure 1). The WWTP is currently being expanded to accomodate increased flows, and extension and relocation of the existing outfall is also being considered as a proactive move to facilitate compliance with State of Hawaii, Department of Health (DOH) regulations. If implemented, the new discharge will be located approximately 3000 meters seaward of the existing one. Figure 1 illustrates the preliminary proposed outfall route alignments.

As part of the planning process, a detailed oceanographic study has been completed, and an environmental impact statement is being prepared. This study is part of the EIS and addresses potential impacts of dredging induced turbidity during construction of the new outfall.

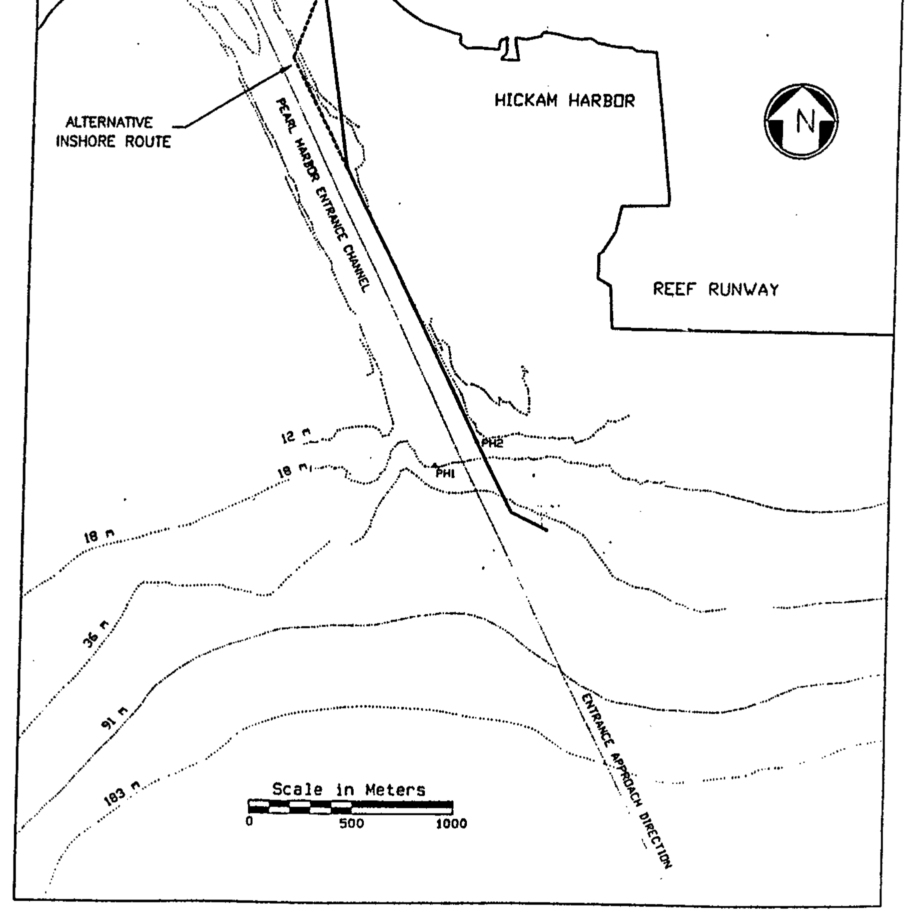
Study Purpose and Scope of Work

The purpose of this study is to assess possible turbidity and suspended solids impacts on coastal water quality as a result of construction of the outfall extension. The scope of work includes the following general tasks:

- review of existing available information pertinent to the study, including dredging turbidity source strengths, suspended solid concentrations vs. turbidity relationships, and previous oceanographic and monitoring studies in the vicinity;
- field investigation of currents and circulation on the reef flat area; and,
- numerical modeling of turbidity plume transport and dispersion to assess possible water quality impacts.

FIGURE 1

PRELIMINARY OUTFALL ROUTE ALIGNMENT



The computer modeling analyses were conducted using an in-house Sea Engineering model that accounts for dredge plume dispersion and particle settling. The modeling and analyses were conducted for four separate zones, based upon the varying bottom characteristics and oceanographic conditions that will be encountered along the route. These areas are illustrated in Figure 2, and include the Fort Kamehameha reef flat, the Pearl Harbor entrance channel, the coral bottom area between the channel and the 20 m depth, and the steeply sloping sandy bottom area beyond the 20 m depth.

The shallow fringing reef flat extends east of the entrance channel from Fort Kamehameha to Sand Island. Sections of the reef have been significantly altered by construction. Extensive dredging created the Pearl Harbor entrance channel, the Hickam Harbor channel and basin, and the entrances to Ke'ehi Lagoon. Massive fill was used to create the Honolulu International Airport Reef Runway. The reef flat in the project area is 1220 m wide between the entrance channel to the west and Hickam Harbor. It is heavily silted near shore, giving way to sand, coral rubble and scattered outcrops of limestone further offshore. A prominent feature is the sandbar formation in the middle of the reef. Inshore of the sandbars, the bottom consists primarily of coarse grey calcareous muddy sand. The sand is thin; probing in several locations indicated less than 6 inches of sand overlying coral cobbles and hard bottom. Seaward of the sandbars, the water depth increases, and colonies of coral begin to occur. The abundance of living corals increases with distance seaward of the sandbars. Coral cover at the seaward regions of the reef flat is approximately 25% of total bottom area. Depth of the reef flat does not exceed 2 m at the seaward limits.

The reef flat terminates at the vertical wall of the dredged Pearl Harbor entrance channel on the west edge. The entrance channel has been dredged to a depth of 15 m. Sea Engineering, Inc. collected sediment samples from six stations located along the east side of the entrance channel between the existing outfall and the seaward end of the channel. The channel bottom along the possible outfall route consists of hard coral bottom, or a thin layer (less than 0.6 m) of fine sand and silt overlying hard coral bottom.

Seaward of the entrance channel to water depths of 18 to 24 m, the bottom consists of patch reefs composed of coral rubble with a component of living corals, interspersed with sand (coral zone in Figure 2). Living coral cover within the patch reefs is estimated to be approximately 20%, and the patch reefs are estimated to comprise up to 10% of the bottom. Seaward of this zone, there is a thick deposit of sand (sand zone in Figure 2). Grain size analysis of surface samples from the deposit showed a trend toward finer sediments with increasing water depths. The grain sizes ranged from coarse sand inshore to very fine sand

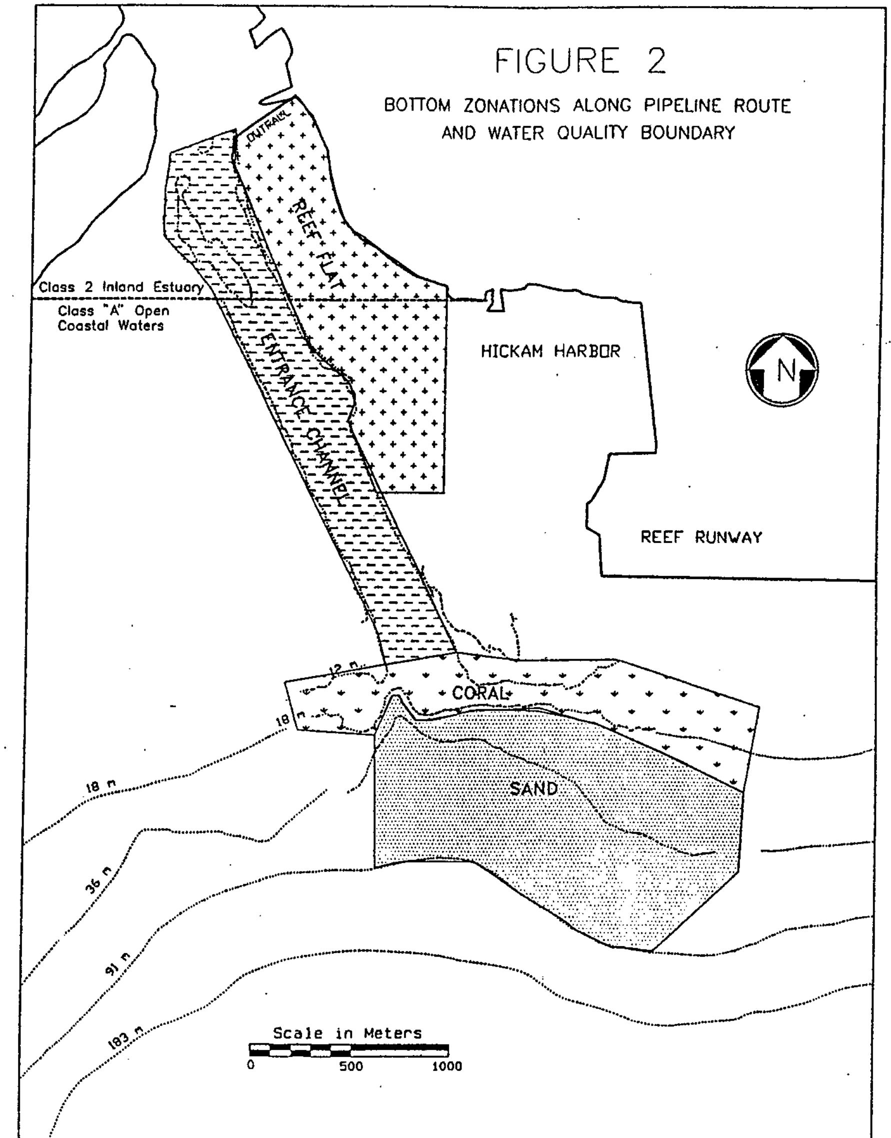


FIGURE 2

BOTTOM ZONATIONS ALONG PIPELINE ROUTE AND WATER QUALITY BOUNDARY

in 48 m of water. The sand depths exceed 6 m throughout much of the deposit, and occasionally exceed 10 m.

2.0 NUMERICAL MODEL

The potential impacts of suspended solids loading in the water column as a result of dredging for the outfall construction can be assessed using numerical modeling techniques. The extent of detailed information obtained during the oceanographic study provides project specific data for model input. Pertinent information is also available from prior investigations during other dredging projects in Hawaii. The modeling calculations of suspended solids plume dilution and transport can then be used to predict turbidity impacts on coastal waters during the proposed project.

The model employed is based on methodology initially developed by Brooks (1959) for estimating plume dilution, and is discussed in detail in Grace (1978) and Fischer et al. (1979). The model basically estimates suspended solids plume spread and centerline concentration decrease by mixing and transport in a uniform current flow, coupled with a concentration decrease by settling due to particle fallout.

Model Theory

The Brooks Model estimates plume spread and centerline concentration by mixing in a uniform current flow (Grace, 1978; Fischer et al., 1979). The analysis assumes that vertical mixing and mixing in the direction of the current are negligible, that the effluent plume has the same density as the ambient water body and moves with the current system, and that mixing in the lateral direction can be described by the diffusion process and a diffusion coefficient.

<u>Basic Equations</u>

The Brooks Model assumes that the initial and subsequent diffusion coefficients are given by the following equations:

$$D_o = \alpha B^n$$

and

$$D = \alpha L_x^n$$

where, D_o = initial diffusion coefficient
D = diffusion coefficient
α, n = empirical constants
B = initial plume width
L_x = nominal plume width ($=(2\sqrt{3})\sigma$).

The value of the exponent n is either 0 (constant diffusion coefficient, typical of small confined coastal areas or estuaries), 1 (typical of coastal situations) or 4/3 (which conforms to Richardson's Law and is typical of open ocean situations). The Brooks Model calculates the rate of decrease of the centerline concentration and the spread of the turbid plume using the following equations:

$$C_x/C_i = \text{erf}\{[1.5/((L_x/B)^2-1)]^{1/2}\}$$

$$L_x/B = [1+2\beta(x/B)]^{1/2} \qquad \text{for } n=0$$

$$L_x/B = [1+\beta(x/B)] \qquad \text{for } n=1$$

$$L_x/B = [1+2\beta(x/B)/3]^{3/2} \qquad \text{for } n=4/3$$

where,

C_x = centerline concentration at a distance x
C_i = initial concentration at x=0
erf{ } = error function
$\beta = 12D_o/(uB)$
u = current speed.

The general form of the equation is as follows:

$$L_x/B = [1+(2-n)\beta(x/B)]^{1/(2-n)}.$$

<u>Decrease in Concentration Due to Sediment Fallout</u>

The above equations are for conservative substances. For non-conservative substances, a decay function of the following form can be used (Grace, 1978):

$$C_x/C_i = \exp(-k_0 t)$$

Where, k_0 = decay rate
t = time.

The reduction in plume concentration due to particle settling can also be estimated using this equation, where $k_0 = w/d$:

$$C_x/C_i = \exp(-wt/d)$$

and, w = fall velocity
d = depth of water.

Fall velocity depends primarily on particle size, and can be approximated by using the following equation (Shore Protection Manual, U.S. Department of the Army, 1984):

$$w = (\gamma_s/\gamma - 1) g d_{50}^2/(18\nu)$$

where, γ_s = specific gravity of suspended sediment (use 2.72 for calcite)
γ = specific gravity of sea water (use 1.022)
g = acceleration of gravity
d_{50} = median grain size
ν = kinematic viscosity of sea water (use 8.5×10^{-3} cm^2/s)

The total concentration decrease for suspended solids generated by dredging activity is then estimated by multiplying the concentration change due to diffusion by the concentration change due to sediment fallout.

3.0 TURBIDITY AND SUSPENDED SOLIDS

Turbidity is measured in terms of nephelometric turbidity units (NTU), which is a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions. The higher the intensity of scattered light, the higher the turbidity. Turbidity is generally related to the concentrations of suspended solids in the water. Suspended solids concentrations represent nonfilterable particulate material in the water, which could be of biological origin (i.e. plankton or algae), or in the vicinity of a dredging operation would represent fine dredged material temporarily suspended in the water column. Suspended solids are presented in milligrams per liter (mg/ℓ).

The State Water Quality Standards for turbidity applicable to the Pearl Harbor entrance channel and the adjacent coastal waters are the following:

	NTU (geometric mean not to exceed the given value)
Pearl Harbor (Class 2 Inland Estuary)	4.0
Open Coastal Waters (Class A, "wet" criteria)	0.5

Source: Hawaii Administrative Rules, Title 11, Department of Health, Chapter 54, Water Quality Standards, 1992.

The water quality standards are presented in terms of the geometric mean (as opposed to the arithmetic mean), as this is considered to best represent the observed concentrations of water quality parameters such as turbidity and suspended solids. In this report, data summaries and averages are presented as geometric means in order to be comparable with State Water Quality Standards.

Turbidity and Suspended Solids Correlation Analysis

The plume transport model, as described above, computes plume concentrations in units of mass per unit of volume. The State Water Quality Standards, however, are specified in terms of nephlometric turbidity units (NTU) — an optical parameter. It is therefore necessary to convert NTU to suspended solids concentrations to compare model results with water quality standards. The most comprehensive data set in Hawaii relating turbidity to suspended solids was collected for the construction of Barbers Point Harbor. AECOS, Inc. (1986) conducted water quality monitoring investigations in the vicinity of the harbor prior to construction activities, for three years during construction, and after construction. This monitoring yielded 448 measurements of both turbidity and suspended solids in the same sample. Regression analysis of this data resulted in the following relationships:

For suspended solids concentration > 6 mg/ℓ:

$$\text{Turbidity (NTU)} = 0.629[\text{Concentration (mg/}\ell)] - 1.18$$

and

For suspended solids concentration ≤ 6 mg/ℓ:

$$\text{Turbidity (NTU)} = 0.220[\text{Concentration (mg/}\ell)]^{1.376}$$

These equations have been incorporated into the numerical model.

4.0 MODEL APPLICATION AND KEY INPUT PARAMETERS

The outfall route and corresponding modeling analyses have been divided into four zones, characterized by distinctive oceanic conditions and bottom types. These zones are the Fort Kamehameha reef flat, the Pear Harbor entrance channel, a coral bottom zone between the entrance channel and the 20 m depth, and a sandy bottom area beyond the 20 m depth (Figure 2). The key variables for the modeling analysis are empirical constant, diffusion coefficient, initial plume concentration, plume depth, sediment grain size, and current speed. Below, we define these parameters and discuss the input values appropriate for each of the four modeling areas.

Empirical Constant α: The constant α is an empirically derived constant. Okubo (1974, In Fischer et al., 1979) give an estimate for α for engineering purposes in the following range:

$$0.002 \le \alpha \le 0.01 \quad cm^{2/3}/s$$

or

$$0.74 \le \alpha \le 3.7 \quad ft^{2/3}/hr.$$

According to Koh and Brooks (1975, In Grace, 1978), the approximate range for α is:

$$1.5x10^{-4} \le \alpha \le 5x10^{-3} \quad ft^{2/3}/s$$

or

$$0.54 \le \alpha \le 18 \quad ft^{2/3}/hr.$$

Pearson (1961, In Grace, 1978) suggested α=0.001 $ft^{2/3}/s$ or 3.6 $ft^{2/3}/hr$.

In this study, we use Pearson's suggested value of 3.6 $ft^{2/3}/hr$ for each of our modeling areas.

Diffusion Coefficient n: The value n is an exponent of the length scale of the turbid field which determines the rate of diffusion. Values of n are typically 0 for small confined coastal areas or estuaries, 1 for coastal situations, and 4/3 for open ocean situations. A value of n=1 was used for modeling the plume on the reef flat and within the entrance channel because of the confined nature of circulation in these areas. A value of n=4/3 was used for the modeling of the coral zone, and sandy zone corresponding to open oceanic conditions.

Plume Depth: The depth of the turbidity plume depends on the water depth and dredging operations. In the reef flat, entrance channel and coral zone, the dredge material will be removed from the water. The plume depth is therefore assumed equivalent to the average water depth in these areas. In the sandy bottom area, the dredged sand will likely be sidecast, rather than removed to the surface. In this case, we assume the plume depth is half of the water depth. The plume depths used in the modeling are the following: 1.2 m in the reef flat, 14 m in the entrance channel, 16 m in the coral zone, and 20 m in the sand zone.

Initial Concentration of Turbid Plume: Reported values of turbid plume concentrations caused by dredging operations vary widely, and depend on dredge type, location in the water column, distance from the dredge and ambient conditions. Herbich (1992) indicates that suspended solids concentrations may range from 30 to 80 mg/ℓ at a distance of 200 feet from an enclosed clamshell dredge. Sustar et al. (1976) report suspended solids of 70 mg/ℓ along the centerline of a clamshell dredge plume.

AECOS, Inc. (1986) conducted a dredge operation monitoring study for the construction of Barbers Point harbor between 1982 and 1984. From a total of 246 surface and near bottom measurements reported by AECOS, seven cases of suspended solids concentrations over 40 mg/ℓ were measured at a distance of about 500 feet from the source during the construction. The maximum measured suspended solids concentration was 64 mg/ℓ near the harbor bottom. Noda and Associates (1990) used a value of 40 mg/ℓ based on these measurements for plume trubidity studies. The initial plume width of approximately 10 m is also estimated for the use of a clam-shell dredge (Noda and Associates, 1990).

On February 1, 1983, clamshell dredging was performed in the barge harbor from 10 am to noon. During excavation of the entrance channel offshore, excavated material was brought into the barge harbor by scow, bottom dumped, and the excavated for removal to stockpiles on land. This sequence of dumping and rehandling in the water is an extreme case of agitating the material that will not occur during the proposed outfall dredging. Right after the dredging operation, turbidity measurements were taken at the sampling stations in the harbor. An aerial photo taken on this day is also available, which shows an obvious turbidity plume in the dredge vicinity. The maximum turbidity measured on the day is 27 NTU. This turbidity data can be converted to a suspended solids load of 45 mg/ℓ using the following turbidty equations described previously.

Based on the above information, we used the initial plume suspended solids concentrations of 70 mg/ℓ for a plume width approximately 10 m wide reported by Sustar et al. (1976). This concentration is considered to be a conservative, worst case condition for the proposed outfall dredging, particularly when combined with the plume depth. The model assumes the initial concentration applies to the entire plume depth; however concentrations of 70 mg/ℓ problably occur only near the bottom.

Suspended Sediment Grain Size and Fall Velocity: Grain size distribution, and the associated grain fall velocities, are important inputs to the plume model. The appropriate grain size for use in the modeling depends on the bottom type in the area being dredged. The dredging will occur in primarily two bottom types: coral or coralline limestone in the reef flat, entrance channel and coral zone, and sand in the sand zone offshore. For the sand zone, we will use the measured grain size distribution of samples we collected in that area (Table 1). The corresponding fall velocities for this sand are presented in Table 2, and illustrate that the sand sized particles predominant in the sample settle out of suspension relatively quickly. The appropriate grain size to use in the other areas is that of coral crushed by the dredging activity. Similar coralline (limestone) material was dredged at

Kawaihae Harbor, and monitoring was conducted to determine grain sizes and suspended sediment loads generated by the dredging. Sullivan and Gerritsen (1972) measured suspended solids grain size distributions near the discharge from a hydraulic cutterhead dredge, and this distribution is a conservative representation of grain size characteristics generated by dredging for the outfall. This represents a conservative input for our modeling because cutterhead dredging crushes the coral to a greater extent than does clamshell dredging that will probably be used for the outfall extension. A typical suspended grain size distribution near the dredge head during the dredging at Kawaihae Harbor is shown on Table 3, and the corresponding fall velocities are illustrated in Table 4. The table shows that most of the sample is silt and finer (<0.063mm) and settles out of suspension slowly, less than 10 m/hr.

TABLE 1. GRAIN SIZE DISTRIBUTION FOR OFFSHORE SANDY BOTTOM ZONE

Phi Value (ϕ)	Size (mm)	Weight Frequency (%)	Cumulative Frequency (%)
<-2	> 4.0	1.0	1.0
-1.0 to -2.0	2.0-4.0	1.9	2.9
-1.0 to 0.0	1.0-2.0	4.9	7.8
0.0 to 1.0	0.5-1.0	10.0	17.8
1.0 to 2.0	0.25-0.5	19.5	37.3
2.0 to 3.0	0.125-0.25	50.0	87.3
3.0 to 4.0	0.063-0.125	10.9	98.2
> 4.0	<0.063	1.8	100

TABLE 2. FALL VELOCITY FOR OFFSHORE SANDY BOTTOM ZONE

Phi Value (ϕ)	Grain Size (mm)	Fall Velocity (m/hr)
-2.0	4.0	963.1
-1.0	2.0	681.0
0.0	1.0	481.5
1.0	0.5	265.1
2.0	0.25	123.7
3.0	0.125	57.7
4.0	0.063	15.2
5.6	0.020	1.53

TABLE 3. TYPICAL SUSPENDED SEDIMENT LOAD GRAIN SIZE DISTRIBUTION NEAR DREDGE HEAD, KAWAIHAE HARBOR DREDGING OPERATION (SULLIVAN AND GERRITSEN, 1972)

Phi Value (ϕ)	Size (mm)	Weight Frequency (%)	Cumulative Frequency (%)
2.0-2.5	0.246-0.177	2	2
2.5-3.0	0.177-0.125	5	7
3.0-3.5	0.125-0.088	7	14
3.5-4.0	0.088-0.0625	4	18
4.0-4.5	0.0625-0.0442	3	21
4.5-5.0	0.0442-0.0313	15	36
5.0-5.5	0.0313-0.0221	40	76
5.5-6.0	0.0221-0.0156	20	96
6.0-6.5	0.0156-0.0110	2	98
6.5-7.0	0.0110-0.0078	2	100
>7.0	0.0078	0	

TABLE 4. FALL VELOCITY FOR KAWAIHAE SUSPENDED SEDIMENT LOAD

Phi Value (ϕ)	Grain Size (mm)	Fall Velocity (m/hr)
2.25	0.210	102.1
2.75	0.150	70.5
3.25	0.110	46.4
3.75	0.074	21.0
4.25	0.053	10.8
4.75	0.037	5.24
5.25	0.026	2.59
5.75	0.019	1.38
6.25	0.013	0.65
6.75	0.009	0.31

Currents:

The currents and circulation vary significantly between each of the four areas for our modeling analysis. Each area therefore requires input of current conditions specific to that area. In the oceanographic study for this project, Sea Engineering, Inc., 1996 deployed current meters for approximately one year in the offshore coral and sandy bottom areas (SSFM, 1996). This data was processed to yield average speeds and frequency of occurrence within sixteen directional sectors, and is presented in Tables 5 and 6. In the coral and sandy zones, our analysis entailed completing modeling runs for each of the directional sectors, using the corresponding average speed and frequency of occurrence presented in Tables 5 and 6.

TABLE 5. CURRENTS MEASURED IN CORAL ZONE: 1/24/95 - 1/16/96

Direction	Frequency of Occurrence (%)	Avg Speed cm/s
Calm	0.1	0
N	2.2	2.9
NNE	3.4	3.0
NE	5.2	4.7
ENE	12.5	9.1
E	13.2	11.6
ESE	4.6	8.4
SE	1.8	4.9
SSE	1.3	3.1
S	0.9	2.7
SSW	1.6	2.6
SW	2.2	4.4
WSW	6.9	9.3
W	26.8	15.4
WNW	10.4	7.5
NW	4.1	3.7
NNW	2.9	2.6
Total	100%	9.6

TABLE 6. CURRENTS MEASURED IN SANDY AREA: 1/24/95 - 12/28/95

Direction	Frequency of Occurrence (%)	Avg Speed cm/s
Calm	7.5	0
N	2.9	3.7
NNE	2.7	3.9
NE	4.0	4.6
ENE	6.3	5.8
E	12.3	7.9
ESE	10.5	7.8
SE	5.6	5.7
SSE	2.8	4.2
S	1.8	3.5
SSW	1.8	3.4
SW	3.1	4.6
WSW	6.0	7.4
W	13.9	10.7
WNW	10.2	8.4
NW	5.3	5.6
NNW	3.2	4.4
Total	100%	6.5

Current speeds in the entrance channel were measured by Bathen (1972). Average currents at mid-depth in the entrance channel were 7.5 cm/s into the harbor during flood tide and 17.5 cm/s out of the harbor during ebb tide. These values were used for our modeling analysis of the entrance channel. Because subsurface currents in the channel are tidally driven, we assumed that the currents were directed into the harbor half of the time, and out of the harbor half of the time.

There is no information available on currents and circulation on the reef flat. For this study, therefore, we conducted drogue measurements on September 5 and October 4, 1996 to characterize currents on the reef flat. The focus of the field measurements were to determine the extent of wind or tidal influence on the currents, and average speeds. On September 5, trade wind conditions prevailed; tide levels were 1.9 feet at 11:33 and 0.6 feet at 19:03. On October 4, wind conditions were light; tide levels were 1.8 feet at 10:32 and 0.5 feet at 18:13. On both days, drogues moved predominantly down wind. On September 5, the average speed was 6 cm/s, and the peak speed measured was 10 cm/s. On October 4, drogues moved more slowly because of the light wind conditions; the peak speed was 7.0

cm/s and the average speed was 3.4 cm/s. These measurements indicate that on the reef flat there is little tidal influence; currents are primarily driven in the direction of the wind. For out modeling analysis, we therefore assumed that the frequency of occurrence of current directions on the reef is well represented by long term wind records recorded at the adjacent airport. Table 7 presents wind records from the airport. (Note that wind and current directions are described in opposite terms --- the direction from which the wind is blowing, and the direction to which the current is flowing.) Our current speed input to the model is 6 cm/s --- based upon the average current speed we measured during typical trade wind conditions on September 5.

TABLE 7. WINDS AT HONOLULU AIRPORT: 1939-1967

Direction	Frequency of Occurrence (%)	Avg Speed cm/s
Calm	4.7	0
N	4.8	5.7
NNE	3.6	7.0
NE	21.5	11.2
ENE	30.9	11.8
E	14.3	10.7
ESE	1.5	8.9
SE	2.2	9.8
SSE	2.2	10.1
S	2.9	9.0
SSW	1.3	9.2
SW	1.3	9.3
WSW	0.6	10.3
W	0.8	7.3
WNW	0.7	5.3
NW	3.9	5.1
NNW	2.8	5.5
Total	100%	9.7

5.0 MODEL RESULTS

The State Water Quality Standards for turbidity are presented as geometric means. Our approach for the modeling analysis was to use inputs and conduct modeling scenarios that best simulate a geometric mean. For each area, this was achieved in the following manner:
1) Obtain long term current data at each site that includes average speeds and frequency of occurrence of currents in all directional sectors. Tables 5 and 6 present such data for the offshore coral and sandy zones. The data indicates, for example, that in the coral area currents flow to the west 27% of the time, and have average speeds of 15.4 cm/s. This means that a dredging turbidity generated in this zone would be transported to the west 27% of the time; the other 73% of the time, the turbidity would be transported in other directions and this area would be free of turbidity. Wind records from the Airport were assumed representative of currents on the reef flat, and current measurements from Bathen (1972) were used for the entrance channel.
2) Compute model runs for each direction of current flow to estimate plume centerline turbidity and width as a function of distance in earch direction from the dredge site.
3) The frequency of occurrence of flow in each direction is then used to calculate the geometric mean turbidity of the plume. For example, in the coral bottom zone, centerline turbidity is calculated to be 1.1 ntu at a distance of 1109 m west of the dredgehead. However, the current flows in this direction only 27% of the time; the remaining 73% of the time, turbidity would be at ambient levels, .121 ntu (SSFM, 1996). Average, or geometric mean, turbidity at this location is then calculated assuming turbidity of 1.1 ntu 27% of the time, and .121 ntu 73% of the time. The geometric mean turbidity in this example is .383 ntu.
4) For each direction, the computed geometric mean turbidity as a function of distance is then compared to DOH water quality standards to determine the distance the plume is transported before turbidity falls below the standards. This distance is then plotted to define a mixing zone of turbidity, within which geometric mean turbidity exceeds DOH standards.

Table 9 summarizes the modeling scenarios we completed, totaling 68 different runs. The numeric output of each of these runs is presented in Appendix A. Figures 3 and 4 summarize the overall results of the modeling. The figures plot the model calculated areas required to meet mean DOH turbidity standards during active dredging at a representative location in the area. Once dredging ceases, turbidity levels would quickly return to ambient levels within these areas.

TABLE 9. TURBIDITY PLUME MODELING INPUTS

Area	Grain Size	Plume Depth (m)	Currents cm/s	Initial Conc. Cl (mg/ℓ)	Plume width (m)	Diffusion Coeff. (a)	Ambient Turbidity (ntu)*	DOH Turbidity Standard (NTU)
Reef Flat	(Sullivan & Gerritsen, 1972) Table 3	1.2	6 (ave)	70	10	1	.369	4.0 0.5
Entrance Channel	(Sullivan & Gerritsen, 1972) Table 3	14 14 14	7.5 (ave. into) 17.5 (ave. out) Table 5	70 70 10	10 10 50	1 1 4/3	.245 .245 .121	0.5 0.5 0.5
Coral	(Sullivan & Gerritsen, 1972) Table 3	16	Table 5	70	10	4/3	.121	0.5
Sand	Table 1	20	Table 6	70	10	4/3	.121	0.5

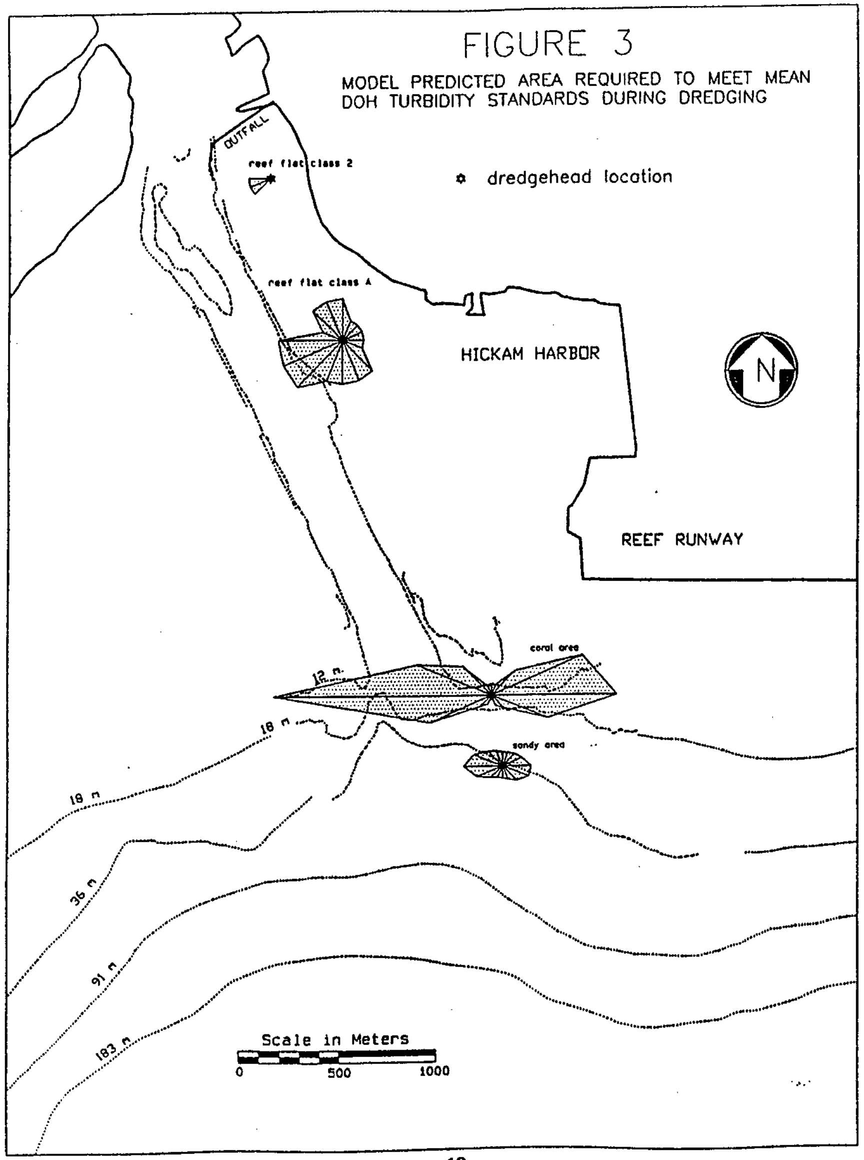
* SSFM, 1996

Reef Flat

As mentioned above, our modeling analysis for the reef flat assumed currents flowing at 6 cm/s, and in directions that correspond to winds recorded at the Airport. The results of our modeling are plotted in Figure 3. Within the reef flat area, water quality standards transition from Class 2 Inland Estuary to Class "A" Coastal Waters (Figure 2). Corresponding turbidity standards, as presented in Table 1, are 4.0 ntu and 0.5 ntu. Our modeling results indicate that during dredging in the estuarine part of the reef flat, only a negligible water mass will experience turbidity that exceeds 4.0 ntu. Turbidity is predicted to exceed 4.0 ntu for a distance of less than 100 m to the west, west-southwest and southwest of the dredge site (Figure 3; Appendix A1, p. 12-14). These directions correspond to the directions of flow during prevailing tradewinds. In the Class A portion of the reef flat, the turbidity standard is 0.5 ntu and the dredging plume must be transported a greater distance and time before turbidity falls within the standard. The area exceeding standards extends approximately 300 meters west, west-southwest and southwest of the dredge site (Figure 3; Appendix A-1, p. (12-14). In other directions, turbidity standards are met within less than 200 m. On the reef flat, the areas exceeding water quality standards during dredging are predicted to be small because the suspended solids quickly fall out of suspension in the shallow water. Settling velocity calculations in the model indicates that in 1.2 m of water, over 90% of the suspended solids settle out of suspension within 1.5 hours (Appendix A1, p.1).

FIGURE 3

MODEL PREDICTED AREA REQUIRED TO MEET MEAN DOH TURBIDITY STANDARDS DURING DREDGING

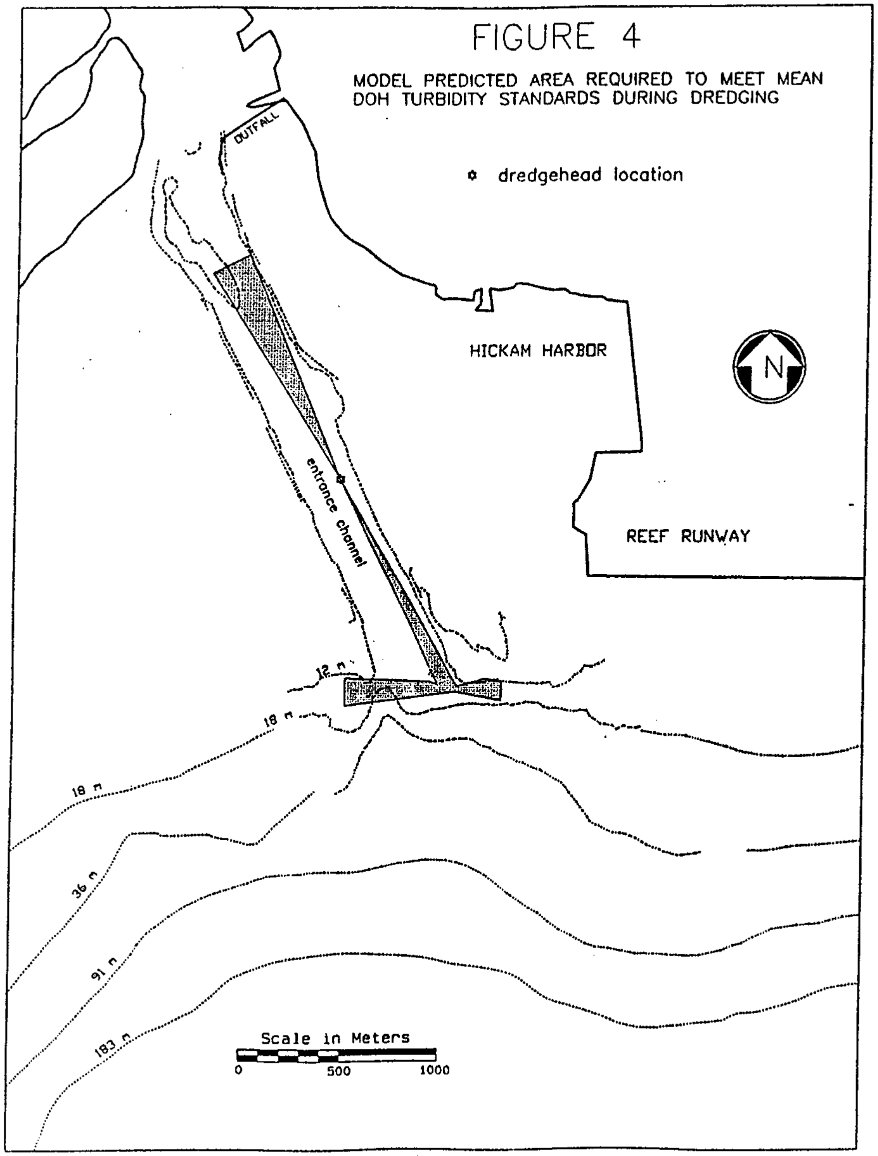


Entrance Channel

Figure 4 and Appendix A-2 present the modeling results for dredging in the entrance channel. The plume is significantly longer than on the reef flat, extending approximately 1200 m into the harbor and beyond the entrance channel to the south. There are three primary reasons for this. First, the plume depth used in the entrance channel is 14 m, the approximate water depth in the channel, compared to 1.2 m on the reef flat. The modeling assumes that the 70 mg/ℓ initial plume concentration applies to the entire plume depth. This represents a worst case input because concentrations of 70 mg/ℓ probably occur only near the bottom. Suspended solids generated by the dredging therefore take much longer to settle out of suspension. After 7 hours of settling, 25% of solids still remain in suspension (Appendix A-2, p. 1). Second, currents are confined to two directions: into the harbor and out of the harbor. The dredging plume, therefore, is not dispersed in all directions. Third, currents are stronger within the entrance channel; average ebb currents out of the harbor are 17.5 cm/s, while average currents into the harbor are 7.5 cm/s. The dredging plume is transported more quickly and farther from the dredging site. At the seaward end of the channel, the plume is calculated to be 50 m wide with a centerline concentration of 10 mg/ℓ. Upon exiting the entrance channel into the open coastal waters, the plume is transported and dispersed by open coastal currents characteristic of the coral bottom zone. We analyzed this scenario by completing a series of modeling runs using as input the model calculated plume width and concentration at the seaward end of the channel, and the currents characterstic of the coral zone (Table 5). These results are plotted in Figure 4 as the east-west trending plume segment at the seaward end of the entrance channel. The plume is predicted to be transported approximately 500 m to the west and 200 m to the east before mean turbidity falls below the standard.

Coral Zone

A coral bottom zone extends outside the entrance channel from a water depth of about 15 m to 20 m. Results of our modeling analysis for this area are presented in Figure 3 and Appendix A-3. Dredging in this area will result in turbidity being transported primarily to the east or west of the dredging site. The model predicted area required to meet mean DOH turbidity standards during dredging extends approximately 600 m to the east and 1100 meters to the west of the dredge site (Appendix A3, p. 6 & 14). This dredging plume is relatively large because the currents in this area are relatively strong, averaging 15.4 cm/s to the west and 11.6 cm/s to the east, and because the fine sediments caused by crushing the coral settle slowly out of suspension. A plume depth of 16 m and initial concentration of 70 mg/ℓ also represent conservative inputs because concentrations of 70 mg/ℓ probably occur only near the bottom.



Sandy Area

Figure 3 and Appendix A-4 present the results of the modeling analysis for the sandy area. The model predicts only a small area is required to meet mean turbidity standards, extending a maximum of 200 m to the west and 140 m to the east of the dredge site. The area of impact is small for several reasons. First, the sandy bottom has very little silt and finer material (Table 1). The sand drops out of suspension relatively quickly. The model sediment fall velocity calculations show that within 0.5 hours 80% of the material has settled, and within 1 hour 90% of the material has settled (Appendix A-4, p. 1). Second, currents are weaker in the deeper water of the sandy area. Currents average 7.9 cm/s to the east, and 10.7 cm/s to the west. Third, current directions are more evenly distributed than in the shallower coral area. Turbidity is therefore dispersed to a greater extent in all directions.

6.0 DISCUSSION

Figures 3 and 4 present the results of our modeling in the form of predicted mixing zones within which turbidity will exceed standards during dredging at representative locations within the four modeling areas. These results are only applicable during active dredging for the specific dredgehead location. We also assume that dredging occurs at that location long enough to experience a range of current conditions. The geometric mean turbidity values we have plotted therefore average in periods where the plume is being transported in another direction. This also means that at any instant during dredging — for example, during periods of strong unidirectional currents — turbidity standards may be exceeded beyond the representative areas illustrated in Figures 3 and 4. On the other hand, we have also used conservative inputs for the initial plume concentration, plume depth and grain size distribution. In addition, we have plotted the model calculated peak plume centerline concentration; the average plume concentration would be 66% of this value.

Our modeling analysis suggests that dredging turbidity impacts should be minimal. On the reef flat and in the sandy zone, the areas predicted to exceed turbidity standards are small. In the entrance channel and coral zone, however, the plume is calculated to extend a significant distance from the dredgehead. This is due to the swifter and bidirectional nature of the currents in these areas, and the conservative grain size distribution used in the analysis. The plume generated by dredging in the entrance channel will remain mostly within the entrance channel, and should therefore have little impact. Dredging in the coral area, however, could generate a turbidity plume that exceeds mean standards for approximately 1100 m to the west and 600 m to the east of the dredging site.

Our model calculations show, however, that the turbidity should be short lived. Once dredging ceases, dispersion and settling quickly reduce turbidity levels to below the 0.5 ntu

mandated by the water quality standards. Table 8 shows the time required after dredging stops for turbidity levels to fall below the water quality standards at the dredgehead, and in the absence of currents. In only 1 hour after dredging stops in the sandy zone, turbidity is dispersed and settled to below the water quality standards. In the sensitive coral area, only 3 hours are required to reduce turbidity to 0.5 ntu. The areas of impact illustrated in Figures 3 and 4 will also shift with the dredgehead location as it moves along the pipeline route. Estimated construction times in each area are 3 months on the reef flat, 6 months in the entrance channel, 1 month in the coral zone, and 1 to 3 months in the sand zone.

TABLE 8. TIME REQUIRED FOR TURBIDITY TO FALL BELOW THE STANDARDS

Area	Time
Reef Flat	1.5
Entrance Channel	7.0
Coral Area	3.0
Sandy Area	1.0

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APPENDIX A

DREDGE TURBIDITY PLUME MODEL OUTPUT

APPENDIX A-1

Reef Flat

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
REEF FLAT, PLUME DEPTH=1.2m

Time (hours)	Relative Concentration Decrease Per Grain Size Fraction (mm) (weight percent listed below grain size)											
	.210	.150	.110	.074	.053	.037	.026	.019	.013	.009	all	(mm)
	.020	.050	.070	.040	.030	.150	.400	.200	.020	.020		(wt %)
.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
.5	.000	.000	.000	.000	.011	.112	.340	.562	.764	.879	.298	
1.0	.000	.000	.000	.000	.000	.013	.116	.316	.583	.772	.138	
1.5	.000	.000	.000	.000	.000	.001	.039	.177	.445	.678	.074	
2.0	.000	.000	.000	.000	.000	.000	.013	.100	.340	.596	.044	
2.5	.000	.000	.000	.000	.000	.000	.005	.056	.260	.524	.029	
3.0	.000	.000	.000	.000	.000	.000	.002	.032	.198	.460	.020	
3.5	.000	.000	.000	.000	.000	.000	.001	.018	.151	.405	.015	
4.0	.000	.000	.000	.000	.000	.000	.000	.010	.116	.355	.011	
4.5	.000	.000	.000	.000	.000	.000	.000	.006	.088	.312	.009	
5.0	.000	.000	.000	.000	.000	.000	.000	.003	.067	.274	.007	
5.5	.000	.000	.000	.000	.000	.000	.000	.002	.051	.241	.006	
6.0	.000	.000	.000	.000	.000	.000	.000	.001	.039	.212	.005	
6.5	.000	.000	.000	.000	.000	.000	.000	.001	.030	.186	.004	
7.0	.000	.000	.000	.000	.000	.000	.000	.000	.023	.164	.004	
7.5	.000	.000	.000	.000	.000	.000	.000	.000	.017	.144	.003	
8.0	.000	.000	.000	.000	.000	.000	.000	.000	.013	.126	.003	

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
REEF FLAT

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 1.2 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.980e-01	3.356e+00
1.0	1.380e-01	7.246e+00
1.5	7.400e-02	1.351e+01
2.0	4.400e-02	2.273e+01
2.5	2.900e-02	3.448e+01
3.0	2.000e-02	5.000e+01
3.5	1.500e-02	6.667e+01
4.0	1.100e-02	9.091e+01
4.5	9.000e-03	1.111e+02
5.0	7.000e-03	1.429e+02
5.5	6.000e-03	1.667e+02
6.0	5.000e-03	2.000e+02

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 1.20 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.060 m/s (2.9 %)
Current Direction : N
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	1.601
.5	108	20.0	4.774e+01	1.423e+01	7.769	.584
1.0	216	30.0	3.214e+01	4.435e+00	1.708	.408
1.5	324	40.1	2.413e+01	1.786e+00	.489	.372
2.0	432	50.1	1.931e+01	8.497e-01	.176	.363
2.5	540	60.1	1.609e+01	4.667e-01	.077	.361
3.0	648	70.1	1.380e+01	2.759e-01	.037	.359
3.5	756	80.1	1.207e+01	1.811e-01	.021	.359
4.0	864	90.2	1.073e+01	1.180e-01	.012	.359
4.5	972	100.2	9.656e+00	8.691e-02	.008	.359
5.0	1080	110.2	8.778e+00	6.145e-02	.005	.358
5.5	1188	120.2	8.047e+00	4.828e-02	.003	.358
6.0	1296	130.2	7.428e+00	3.714e-02	.002	.358

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
REEF FLAT

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 1.2 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.980e-01	3.356e+00
1.0	1.380e-01	7.246e+00
1.5	7.400e-02	1.351e+01
2.0	4.400e-02	2.273e+01
2.5	2.900e-02	3.448e+01
3.0	2.000e-02	5.000e+01
3.5	1.500e-02	6.667e+01
4.0	1.100e-02	9.091e+01
4.5	9.000e-03	1.111e+02
5.0	7.000e-03	1.429e+02
5.5	6.000e-03	1.667e+02
6.0	5.000e-03	2.000e+02

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 1.20 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.060 m/s (1.3 %)
Current Direction : NNE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	.921
.5	108	20.0	4.774e+01	1.423e+01	7.769	.465
1.0	216	30.0	3.214e+01	4.435e+00	1.708	.386
1.5	324	40.1	2.413e+01	1.786e+00	.489	.371
2.0	432	50.1	1.931e+01	8.497e-01	.176	.366
2.5	540	60.1	1.609e+01	4.667e-01	.077	.365
3.0	648	70.1	1.380e+01	2.759e-01	.037	.365
3.5	756	80.1	1.207e+01	1.811e-01	.021	.364
4.0	864	90.2	1.073e+01	1.180e-01	.012	.364
4.5	972	100.2	9.656e+00	8.691e-02	.008	.364
5.0	1080	110.2	8.778e+00	6.145e-02	.005	.364
5.5	1188	120.2	8.047e+00	4.828e-02	.003	.364
6.0	1296	130.2	7.428e+00	3.714e-02	.002	.364

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
REEF FLAT

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 1.2 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.980e-01	3.356e+00
1.0	1.380e-01	7.246e+00
1.5	7.400e-02	1.351e+01
2.0	4.400e-02	2.273e+01
2.5	2.900e-02	3.448e+01
3.0	2.000e-02	5.000e+01
3.5	1.500e-02	6.667e+01
4.0	1.100e-02	9.091e+01
4.5	9.000e-03	1.111e+02
5.0	7.000e-03	1.429e+02
5.5	6.000e-03	1.667e+02
6.0	5.000e-03	2.000e+02

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 1.20 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.060 m/s (1.3 %)
Current Direction : NE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	.921
.5	108	20.0	4.774e+01	1.423e+01	7.769	.465
1.0	216	30.0	3.214e+01	4.435e+00	1.708	.386
1.5	324	40.1	2.413e+01	1.786e+00	.489	.371
2.0	432	50.1	1.931e+01	8.497e-01	.176	.366
2.5	540	60.1	1.609e+01	4.667e-01	.077	.365
3.0	648	70.1	1.380e+01	2.759e-01	.037	.365
3.5	756	80.1	1.207e+01	1.811e-01	.021	.364
4.0	864	90.2	1.073e+01	1.180e-01	.012	.364
4.5	972	100.2	9.656e+00	8.691e-02	.008	.364
5.0	1080	110.2	8.778e+00	6.145e-02	.005	.364
5.5	1188	120.2	8.047e+00	4.828e-02	.003	.364
6.0	1296	130.2	7.428e+00	3.714e-02	.002	.364

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
REEF FLAT

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 1.2 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.980e-01	3.356e+00
1.0	1.380e-01	7.246e+00
1.5	7.400e-02	1.351e+01
2.0	4.400e-02	2.273e+01
2.5	2.900e-02	3.448e+01
3.0	2.000e-02	5.000e+01
3.5	1.500e-02	6.667e+01
4.0	1.100e-02	9.091e+01
4.5	9.000e-03	1.111e+02
5.0	7.000e-03	1.429e+02
5.5	6.000e-03	1.667e+02
6.0	5.000e-03	2.000e+02

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 1.20 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.060 m/s (.6 %)
Current Direction : ENE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	.624
.5	108	20.0	4.774e+01	1.423e+01	7.769	.413
1.0	216	30.0	3.214e+01	4.435e+00	1.708	.377
1.5	324	40.1	2.413e+01	1.786e+00	.489	.370
2.0	432	50.1	1.931e+01	8.497e-01	.176	.368
2.5	540	60.1	1.609e+01	4.667e-01	.077	.367
3.0	648	70.1	1.380e+01	2.759e-01	.037	.367
3.5	756	80.1	1.207e+01	1.811e-01	.021	.367
4.0	864	90.2	1.073e+01	1.180e-01	.012	.367
4.5	972	100.2	9.656e+00	8.691e-02	.008	.367
5.0	1080	110.2	8.778e+00	6.145e-02	.005	.367
5.5	1188	120.2	8.047e+00	4.828e-02	.003	.367
6.0	1296	130.2	7.428e+00	3.714e-02	.002	.367

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
REEF FLAT

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 1.2 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.980e-01	3.356e+00
1.0	1.380e-01	7.246e+00
1.5	7.400e-02	1.351e+01
2.0	4.400e-02	2.273e+01
2.5	2.900e-02	3.448e+01
3.0	2.000e-02	5.000e+01
3.5	1.500e-02	6.667e+01
4.0	1.100e-02	9.091e+01
4.5	9.000e-03	1.111e+02
5.0	7.000e-03	1.429e+02
5.5	6.000e-03	1.667e+02
6.0	5.000e-03	2.000e+02

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 1.20 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.060 m/s (.8 %)
Current Direction : E
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	.709
.5	108	20.0	4.774e+01	1.423e+01	7.769	.428
1.0	216	30.0	3.214e+01	4.435e+00	1.708	.380
1.5	324	40.1	2.413e+01	1.786e+00	.489	.370
2.0	432	50.1	1.931e+01	8.497e-01	.176	.367
2.5	540	60.1	1.609e+01	4.667e-01	.077	.367
3.0	648	70.1	1.380e+01	2.759e-01	.037	.366
3.5	756	80.1	1.207e+01	1.811e-01	.021	.366
4.0	864	90.2	1.073e+01	1.180e-01	.012	.366
4.5	972	100.2	9.656e+00	8.691e-02	.008	.366
5.0	1080	110.2	8.778e+00	6.145e-02	.005	.366
5.5	1188	120.2	8.047e+00	4.828e-02	.003	.366
6.0	1296	130.2	7.428e+00	3.714e-02	.002	.366

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
REEF FLAT

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 1.2 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.980e-01	3.356e+00
1.0	1.380e-01	7.246e+00
1.5	7.400e-02	1.351e+01
2.0	4.400e-02	2.273e+01
2.5	2.900e-02	3.448e+01
3.0	2.000e-02	5.000e+01
3.5	1.500e-02	6.667e+01
4.0	1.100e-02	9.091e+01
4.5	9.000e-03	1.111e+02
5.0	7.000e-03	1.429e+02
5.5	6.000e-03	1.667e+02
6.0	5.000e-03	2.000e+02

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 1.20 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.060 m/s (.7 %)
Current Direction : ESE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	.666
.5	108	20.0	4.774e+01	1.423e+01	7.769	.421
1.0	216	30.0	3.214e+01	4.435e+00	1.708	.378
1.5	324	40.1	2.413e+01	1.786e+00	.489	.370
2.0	432	50.1	1.931e+01	8.497e-01	.176	.368
2.5	540	60.1	1.609e+01	4.667e-01	.077	.367
3.0	648	70.1	1.380e+01	2.759e-01	.037	.367
3.5	756	80.1	1.207e+01	1.811e-01	.021	.367
4.0	864	90.2	1.073e+01	1.180e-01	.012	.366
4.5	972	100.2	9.656e+00	8.691e-02	.008	.366
5.0	1080	110.2	8.778e+00	6.145e-02	.005	.366
5.5	1188	120.2	8.047e+00	4.828e-02	.003	.366
6.0	1296	130.2	7.428e+00	3.714e-02	.002	.366

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
REEF FLAT

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 1.2 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.980e-01	3.356e+00
1.0	1.380e-01	7.246e+00
1.5	7.400e-02	1.351e+01
2.0	4.400e-02	2.273e+01
2.5	2.900e-02	3.448e+01
3.0	2.000e-02	5.000e+01
3.5	1.500e-02	6.667e+01
4.0	1.100e-02	9.091e+01
4.5	9.000e-03	1.111e+02
5.0	7.000e-03	1.429e+02
5.5	6.000e-03	1.667e+02
6.0	5.000e-03	2.000e+02

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 1.20 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.060 m/s (3.9 %)
Current Direction : SE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width - (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	2.026
.5	108	20.0	4.774e+01	1.423e+01	7.769	.658
1.0	216	30.0	3.214e+01	4.435e+00	1.708	.421
1.5	324	40.1	2.413e+01	1.786e+00	.489	.374
2.0	432	50.1	1.931e+01	8.497e-01	.176	.361
2.5	540	60.1	1.609e+01	4.667e-01	.077	.358
3.0	648	70.1	1.380e+01	2.759e-01	.037	.356
3.5	756	80.1	1.207e+01	1.811e-01	.021	.355
4.0	864	90.2	1.073e+01	1.180e-01	.012	.355
4.5	972	100.2	9.656e+00	8.691e-02	.008	.355
5.0	1080	110.2	8.778e+00	6.145e-02	.005	.355
5.5	1188	120.2	8.047e+00	4.828e-02	.003	.355
6.0	1296	130.2	7.428e+00	3.714e-02	.002	.355

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
REEF FLAT

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 1.2 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.980e-01	3.356e+00
1.0	1.380e-01	7.246e+00
1.5	7.400e-02	1.351e+01
2.0	4.400e-02	2.273e+01
2.5	2.900e-02	3.448e+01
3.0	2.000e-02	5.000e+01
3.5	1.500e-02	6.667e+01
4.0	1.100e-02	9.091e+01
4.5	9.000e-03	1.111e+02
5.0	7.000e-03	1.429e+02
5.5	6.000e-03	1.667e+02
6.0	5.000e-03	2.000e+02

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 1.20 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.060 m/s (2.8 %)
Current Direction : SSE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width - (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	1.558
.5	108	20.0	4.774e+01	1.423e+01	7.769	.576
1.0	216	30.0	3.214e+01	4.435e+00	1.708	.406
1.5	324	40.1	2.413e+01	1.786e+00	.489	.372
2.0	432	50.1	1.931e+01	8.497e-01	.176	.364
2.5	540	60.1	1.609e+01	4.667e-01	.077	.361
3.0	648	70.1	1.380e+01	2.759e-01	.037	.360
3.5	756	80.1	1.207e+01	1.811e-01	.021	.359
4.0	864	90.2	1.073e+01	1.180e-01	.012	.359
4.5	972	100.2	9.656e+00	8.691e-02	.008	.359
5.0	1080	110.2	8.778e+00	6.145e-02	.005	.359
5.5	1188	120.2	8.047e+00	4.828e-02	.003	.359
6.0	1296	130.2	7.428e+00	3.714e-02	.002	.359

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
REEF FLAT

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 1.2 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.980e-01	3.356e+00
1.0	1.380e-01	7.246e+00
1.5	7.400e-02	1.351e+01
2.0	4.400e-02	2.273e+01
2.5	2.900e-02	3.448e+01
3.0	2.000e-02	5.000e+01
3.5	1.500e-02	6.667e+01
4.0	1.100e-02	9.091e+01
4.5	9.000e-03	1.111e+02
5.0	7.000e-03	1.429e+02
5.5	6.000e-03	1.667e+02
6.0	5.000e-03	2.000e+02

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 1.20 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.060 m/s (4.8 %)
Current Direction : S
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	2.408
.5	108	20.0	4.774e+01	1.423e+01	7.769	.724
1.0	216	30.0	3.214e+01	4.435e+00	1.708	.433
1.5	324	40.1	2.413e+01	1.786e+00	.489	.375
2.0	432	50.1	1.931e+01	8.497e-01	.176	.360
2.5	540	60.1	1.609e+01	4.667e-01	.077	.355
3.0	648	70.1	1.380e+01	2.759e-01	.037	.353
3.5	756	80.1	1.207e+01	1.811e-01	.021	.352
4.0	864	90.2	1.073e+01	1.180e-01	.012	.352
4.5	972	100.2	9.656e+00	8.691e-02	.008	.352
5.0	1080	110.2	8.778e+00	6.145e-02	.005	.352
5.5	1188	120.2	8.047e+00	4.828e-02	.003	.351
6.0	1296	130.2	7.428e+00	3.714e-02	.002	.351

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
REEF FLAT

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 1.2 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.980e-01	3.356e+00
1.0	1.380e-01	7.246e+00
1.5	7.400e-02	1.351e+01
2.0	4.400e-02	2.273e+01
2.5	2.900e-02	3.448e+01
3.0	2.000e-02	5.000e+01
3.5	1.500e-02	6.667e+01
4.0	1.100e-02	9.091e+01
4.5	9.000e-03	1.111e+02
5.0	7.000e-03	1.429e+02
5.5	6.000e-03	1.667e+02
6.0	5.000e-03	2.000e+02

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 1.20 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.060 m/s (3.6 %)
Current Direction : SSW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	1.898
.5	108	20.0	4.774e+01	1.423e+01	7.769	.635
1.0	216	30.0	3.214e+01	4.435e+00	1.708	.417
1.5	324	40.1	2.413e+01	1.786e+00	.489	.373
2.0	432	50.1	1.931e+01	8.497e-01	.176	.362
2.5	540	60.1	1.609e+01	4.667e-01	.077	.358
3.0	648	70.1	1.380e+01	2.759e-01	.037	.357
3.5	756	80.1	1.207e+01	1.811e-01	.021	.356
4.0	864	90.2	1.073e+01	1.180e-01	.012	.356
4.5	972	100.2	9.656e+00	8.691e-02	.008	.356
5.0	1080	110.2	8.778e+00	6.145e-02	.005	.356
5.5	1188	120.2	8.047e+00	4.828e-02	.003	.356
6.0	1296	130.2	7.428e+00	3.714e-02	.002	.356

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
REEF FLAT

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 1.2 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.980e-01	3.356e+00
1.0	1.380e-01	7.246e+00
1.5	7.400e-02	1.351e+01
2.0	4.400e-02	2.273e+01
2.5	2.900e-02	3.448e+01
3.0	2.000e-02	5.000e+01
3.5	1.500e-02	6.667e+01
4.0	1.100e-02	9.091e+01
4.5	9.000e-03	1.111e+02
5.0	7.000e-03	1.429e+02
5.5	6.000e-03	1.667e+02
6.0	5.000e-03	2.000e+02

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 1.20 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.060 m/s (21.5 %)
Current Direction : SW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width - (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	9.502
.5	108	20.0	4.774e+01	1.423e+01	7.769	1.960
1.0	216	30.0	3.214e+01	4.435e+00	1.708	.657
1.5	324	40.1	2.413e+01	1.786e+00	.489	.395
2.0	432	50.1	1.931e+01	8.497e-01	.176	.327
2.5	540	60.1	1.609e+01	4.667e-01	.077	.306
3.0	648	70.1	1.380e+01	2.759e-01	.037	.298
3.5	756	80.1	1.207e+01	1.811e-01	.021	.294
4.0	864	90.2	1.073e+01	1.180e-01	.012	.292
4.5	972	100.2	9.656e+00	8.691e-02	.008	.291
5.0	1080	110.2	8.778e+00	6.145e-02	.005	.291
5.5	1188	120.2	8.047e+00	4.828e-02	.003	.290
6.0	1296	130.2	7.428e+00	3.714e-02	.002	.290

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
REEF FLAT

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 1.2 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.980e-01	3.356e+00
1.0	1.380e-01	7.246e+00
1.5	7.400e-02	1.351e+01
2.0	4.400e-02	2.273e+01
2.5	2.900e-02	3.448e+01
3.0	2.000e-02	5.000e+01
3.5	1.500e-02	6.667e+01
4.0	1.100e-02	9.091e+01
4.5	9.000e-03	1.111e+02
5.0	7.000e-03	1.429e+02
5.5	6.000e-03	1.667e+02
6.0	5.000e-03	2.000e+02

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 1.20 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.060 m/s (30.9 %)
Current Direction : WSW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width - (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	13.496
.5	108	20.0	4.774e+01	1.423e+01	7.769	2.656
1.0	216	30.0	3.214e+01	4.435e+00	1.708	.783
1.5	324	40.1	2.413e+01	1.786e+00	.489	.406
2.0	432	50.1	1.931e+01	8.497e-01	.176	.309
2.5	540	60.1	1.609e+01	4.667e-01	.077	.279
3.0	648	70.1	1.380e+01	2.759e-01	.037	.267
3.5	756	80.1	1.207e+01	1.811e-01	.021	.261
4.0	864	90.2	1.073e+01	1.180e-01	.012	.259
4.5	972	100.2	9.656e+00	8.691e-02	.008	.257
5.0	1080	110.2	8.778e+00	6.145e-02	.005	.256
5.5	1188	120.2	8.047e+00	4.828e-02	.003	.256
6.0	1296	130.2	7.428e+00	3.714e-02	.002	.256

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
REEF FLAT

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 1.2 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.980e-01	3.356e+00
1.0	1.380e-01	7.246e+00
1.5	7.400e-02	1.351e+01
2.0	4.400e-02	2.273e+01
2.5	2.900e-02	3.448e+01
3.0	2.000e-02	5.000e+01
3.5	1.500e-02	6.667e+01
4.0	1.100e-02	9.091e+01
4.5	9.000e-03	1.111e+02
5.0	7.000e-03	1.429e+02
5.5	6.000e-03	1.667e+02
6.0	5.000e-03	2.000e+02

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 1.20 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.060 m/s (14.3 %)
Current Direction : W
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	6.444
.5	108	20.0	4.774e+01	1.423e+01	7.769	1.427
1.0	216	30.0	3.214e+01	4.435e+00	1.708	.561
1.5	324	40.1	2.413e+01	1.786e+00	.489	.386
2.0	432	50.1	1.931e+01	8.497e-01	.176	.341
2.5	540	60.1	1.609e+01	4.667e-01	.077	.327
3.0	648	70.1	1.380e+01	2.759e-01	.037	.322
3.5	756	80.1	1.207e+01	1.811e-01	.021	.319
4.0	864	90.2	1.073e+01	1.180e-01	.012	.318
4.5	972	100.2	9.656e+00	8.691e-02	.008	.317
5.0	1080	110.2	8.778e+00	6.145e-02	.005	.317
5.5	1188	120.2	8.047e+00	4.828e-02	.003	.317
6.0	1296	130.2	7.428e+00	3.714e-02	.002	.317

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
REEF FLAT

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 1.2 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.980e-01	3.356e+00
1.0	1.380e-01	7.246e+00
1.5	7.400e-02	1.351e+01
2.0	4.400e-02	2.273e+01
2.5	2.900e-02	3.448e+01
3.0	2.000e-02	5.000e+01
3.5	1.500e-02	6.667e+01
4.0	1.100e-02	9.091e+01
4.5	9.000e-03	1.111e+02
5.0	7.000e-03	1.429e+02
5.5	6.000e-03	1.667e+02
6.0	5.000e-03	2.000e+02

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 1.20 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.060 m/s (1.5 %)
Current Direction : WNW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	1.006
.5	108	20.0	4.774e+01	1.423e+01	7.769	.480
1.0	216	30.0	3.214e+01	4.435e+00	1.708	.389
1.5	324	40.1	2.413e+01	1.786e+00	.489	.371
2.0	432	50.1	1.931e+01	8.497e-01	.176	.366
2.5	540	60.1	1.609e+01	4.667e-01	.077	.365
3.0	648	70.1	1.380e+01	2.759e-01	.037	.364
3.5	756	80.1	1.207e+01	1.811e-01	.021	.364
4.0	864	90.2	1.073e+01	1.180e-01	.012	.364
4.5	972	100.2	9.656e+00	8.691e-02	.008	.364
5.0	1080	110.2	8.778e+00	6.145e-02	.005	.364
5.5	1188	120.2	8.047e+00	4.828e-02	.003	.364
6.0	1296	130.2	7.428e+00	3.714e-02	.002	.364

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
REEF FLAT

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 1.2 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.980e-01	3.356e+00
1.0	1.380e-01	7.246e+00
1.5	7.400e-02	1.351e+01
2.0	4.400e-02	2.273e+01
2.5	2.900e-02	3.448e+01
3.0	2.000e-02	5.000e+01
3.5	1.500e-02	6.667e+01
4.0	1.100e-02	9.091e+01
4.5	9.000e-03	1.111e+02
5.0	7.000e-03	1.429e+02
5.5	6.000e-03	1.667e+02
6.0	5.000e-03	2.000e+02

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 1.20 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.060 m/s (2.2 %)
Current Direction : NW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	1.304
.5	108	20.0	4.774e+01	1.423e+01	7.769	.532
1.0	216	30.0	3.214e+01	4.435e+00	1.708	.398
1.5	324	40.1	2.413e+01	1.786e+00	.489	.372
2.0	432	50.1	1.931e+01	8.497e-01	.176	.365
2.5	540	60.1	1.609e+01	4.667e-01	.077	.363
3.0	648	70.1	1.380e+01	2.759e-01	.037	.362
3.5	756	80.1	1.207e+01	1.811e-01	.021	.361
4.0	864	90.2	1.073e+01	1.180e-01	.012	.361
4.5	972	100.2	9.656e+00	8.691e-02	.008	.361
5.0	1080	110.2	8.778e+00	6.145e-02	.005	.361
5.5	1188	120.2	8.047e+00	4.828e-02	.003	.361
6.0	1296	130.2	7.428e+00	3.714e-02	.002	.361

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
REEF FLAT

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 1.2 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.980e-01	3.356e+00
1.0	1.380e-01	7.246e+00
1.5	7.400e-02	1.351e+01
2.0	4.400e-02	2.273e+01
2.5	2.900e-02	3.448e+01
3.0	2.000e-02	5.000e+01
3.5	1.500e-02	6.667e+01
4.0	1.100e-02	9.091e+01
4.5	9.000e-03	1.111e+02
5.0	7.000e-03	1.429e+02
5.5	6.000e-03	1.667e+02
6.0	5.000e-03	2.000e+02

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 1.20 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.060 m/s (2.2 %)
Current Direction : NNW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	1.304
.5	108	20.0	4.774e+01	1.423e+01	7.769	.532
1.0	216	30.0	3.214e+01	4.435e+00	1.708	.398
1.5	324	40.1	2.413e+01	1.786e+00	.489	.372
2.0	432	50.1	1.931e+01	8.497e-01	.176	.365
2.5	540	60.1	1.609e+01	4.667e-01	.077	.363
3.0	648	70.1	1.380e+01	2.759e-01	.037	.362
3.5	756	80.1	1.207e+01	1.811e-01	.021	.361
4.0	864	90.2	1.073e+01	1.180e-01	.012	.361
4.5	972	100.2	9.656e+00	8.691e-02	.008	.361
5.0	1080	110.2	8.778e+00	6.145e-02	.005	.361
5.5	1188	120.2	8.047e+00	4.828e-02	.003	.361
6.0	1296	130.2	7.428e+00	3.714e-02	.002	.361

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
REEF FLAT

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 1.2 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.980e-01	3.356e+00
1.0	1.380e-01	7.246e+00
1.5	7.400e-02	1.351e+01
2.0	4.400e-02	2.273e+01
2.5	2.900e-02	3.448e+01
3.0	2.000e-02	5.000e+01
3.5	1.500e-02	6.667e+01
4.0	1.100e-02	9.091e+01
4.5	9.000e-03	1.111e+02
5.0	7.000e-03	1.429e+02
5.5	6.000e-03	1.667e+02
6.0	5.000e-03	2.000e+02

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 1.20 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.000 m/s (4.7 %)
Current Direction : CALM
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	2.366
.5	0	20.0	4.774e+01	1.423e+01	7.769	.717
1.0	0	30.0	3.214e+01	4.435e+00	1.708	.432
1.5	1	40.1	2.413e+01	1.786e+00	.489	.375
2.0	1	50.1	1.931e+01	8.497e-01	.176	.360
2.5	1	60.1	1.609e+01	4.667e-01	.077	.355
3.0	1	70.1	1.380e+01	2.759e-01	.037	.353
3.5	1	80.1	1.207e+01	1.811e-01	.021	.353
4.0	1	90.2	1.073e+01	1.180e-01	.012	.352
4.5	2	100.2	9.656e+00	8.691e-02	.008	.352
5.0	2	110.2	8.778e+00	6.145e-02	.005	.352
5.5	2	120.2	8.047e+00	4.828e-02	.003	.352
6.0	2	130.2	7.428e+00	3.714e-02	.002	.352

APPENDIX A-2

Entrance Channel

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
ENTRANCE CHANNEL, PLUME DEPTH=14m

Relative Concentration Decrease Per Grain Size Fraction (mm)
(weight percent listed below grain size)

Time (hours)	.210 / .020	.150 / .050	.110 / .070	.074 / .040	.053 / .030	.037 / .150	.026 / .400	.019 / .200	.013 / .020	.009 / .020	all	(mm) / (wt %)
.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
.5	.026	.081	.191	.473	.681	.829	.912	.952	.977	.989	.776	
1.0	.001	.006	.036	.223	.464	.688	.831	.906	.955	.978	.681	
1.5	.000	.001	.007	.106	.316	.570	.758	.862	.933	.967	.613	
2.0	.000	.000	.001	.050	.215	.473	.691	.821	.912	.957	.557	
2.5	.000	.000	.000	.024	.146	.392	.630	.781	.891	.946	.509	
3.0	.000	.000	.000	.011	.100	.325	.574	.744	.870	.936	.467	
3.5	.000	.000	.000	.005	.068	.269	.523	.708	.851	.925	.429	
4.0	.000	.000	.000	.002	.046	.223	.477	.674	.831	.915	.396	
4.5	.000	.000	.000	.001	.031	.185	.435	.641	.812	.905	.365	
5.0	.000	.000	.000	.001	.021	.154	.397	.610	.794	.895	.338	
5.5	.000	.000	.000	.000	.015	.127	.362	.581	.775	.885	.314	
6.0	.000	.000	.000	.000	.010	.106	.330	.553	.758	.875	.291	
6.5	.000	.000	.000	.000	.007	.088	.300	.526	.740	.866	.271	
7.0	.000	.000	.000	.000	.005	.073	.274	.501	.723	.856	.252	
7.5	.000	.000	.000	.000	.003	.060	.250	.477	.707	.847	.235	
8.0	.000	.000	.000	.000	.002	.050	.228	.454	.691	.838	.220	

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
ENTRANCE CHANNEL

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 14 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	7.760e-01	1.289e+00
1.0	6.810e-01	1.468e+00
1.5	6.130e-01	1.631e+00
2.0	5.570e-01	1.795e+00
2.5	5.090e-01	1.965e+00
3.0	4.670e-01	2.141e+00
3.5	4.290e-01	2.331e+00
4.0	3.960e-01	2.525e+00
4.5	3.650e-01	2.740e+00
5.0	3.380e-01	2.959e+00
5.5	3.140e-01	3.185e+00
6.0	2.910e-01	3.436e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 14.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.075 m/s (25 %)
Current Direction : NNW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	10.896
.5	135	20.0	4.774e+01	3.705e+01	22.124	5.715
1.0	270	30.0	3.214e+01	2.189e+01	12.586	3.330
1.5	405	40.1	2.413e+01	1.479e+01	8.125	2.215
2.0	540	50.1	1.931e+01	1.076e+01	5.586	1.580
2.5	675	60.1	1.609e+01	8.192e+00	3.973	1.177
3.0	810	70.1	1.380e+01	6.442e+00	2.872	.902
3.5	945	80.1	1.207e+01	5.178e+00	2.114	.712
4.0	1080	90.2	1.073e+01	4.249e+00	1.610	.586
4.5	1215	100.2	9.656e+00	3.525e+00	1.245	.495
5.0	1350	110.2	8.778e+00	2.967e+00	.983	.429
5.5	1485	120.2	8.047e+00	2.527e+00	.788	.381
6.0	1620	130.2	7.428e+00	2.161e+00	.635	.343

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
ENTRANCE CHANNEL

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 14 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	7.760e-01	1.289e+00
1.0	6.810e-01	1.468e+00
1.5	6.130e-01	1.631e+00
2.0	5.570e-01	1.795e+00
2.5	5.090e-01	1.965e+00
3.0	4.670e-01	2.141e+00
3.5	4.290e-01	2.331e+00
4.0	3.960e-01	2.525e+00
4.5	3.650e-01	2.740e+00
5.0	3.380e-01	2.959e+00
5.5	3.140e-01	3.185e+00
6.0	2.910e-01	3.436e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 14.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.075 m/s (25 %)
Current Direction : NNW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	10.896
.5	135	20.0	4.774e+01	3.705e+01	22.124	5.715
1.0	270	30.0	3.214e+01	2.189e+01	12.586	3.330
1.5	405	40.1	2.413e+01	1.479e+01	8.125	2.215
2.0	540	50.1	1.931e+01	1.076e+01	5.586	1.580
2.5	675	60.1	1.609e+01	8.192e+00	3.973	1.177
3.0	810	70.1	1.380e+01	6.442e+00	2.872	.902
3.5	945	80.1	1.207e+01	5.178e+00	2.114	.712
4.0	1080	90.2	1.073e+01	4.249e+00	1.610	.586
4.5	1215	100.2	9.656e+00	3.525e+00	1.245	.495
5.0	1350	110.2	8.778e+00	2.967e+00	.983	.429
5.5	1485	120.2	8.047e+00	2.527e+00	.788	.381
6.0	1620	130.2	7.428e+00	2.161e+00	.635	.343

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
ENTRANCE CHANNEL

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 14 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	7.760e-01	1.289e+00
1.0	6.810e-01	1.468e+00
1.5	6.130e-01	1.631e+00
2.0	5.570e-01	1.795e+00
2.5	5.090e-01	1.965e+00
3.0	4.670e-01	2.141e+00
3.5	4.290e-01	2.331e+00
4.0	3.960e-01	2.525e+00
4.5	3.650e-01	2.740e+00
5.0	3.380e-01	2.959e+00
5.5	3.140e-01	3.185e+00
6.0	2.910e-01	3.436e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 14.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.175 m/s (25 %)
Current Direction : SSE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	10.896
.5	315	20.0	4.774e+01	3.705e+01	22.124	5.715
1.0	630	30.0	3.214e+01	2.189e+01	12.586	3.330
1.5	945	40.1	2.413e+01	1.479e+01	8.125	2.215
2.0	1260	50.1	1.931e+01	1.076e+01	5.586	1.580
2.5	1575	60.1	1.609e+01	8.192e+00	3.973	1.177
3.0	1890	70.1	1.380e+01	6.442e+00	2.872	.902
3.5	2205	80.1	1.207e+01	5.178e+00	2.114	.712
4.0	2520	90.2	1.073e+01	4.249e+00	1.610	.586
4.5	2835	100.2	9.656e+00	3.525e+00	1.245	.495
5.0	3150	110.2	8.778e+00	2.967e+00	.983	.429
5.5	3465	120.2	8.047e+00	2.527e+00	.788	.381
6.0	3780	130.2	7.428e+00	2.161e+00	.635	.343

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
ENTRANCE CHANNEL

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 14 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	7.760e-01	1.289e+00
1.0	6.810e-01	1.468e+00
1.5	6.130e-01	1.631e+00
2.0	5.570e-01	1.795e+00
2.5	5.090e-01	1.965e+00
3.0	4.670e-01	2.141e+00
3.5	4.290e-01	2.331e+00
4.0	3.960e-01	2.525e+00
4.5	3.650e-01	2.740e+00
5.0	3.380e-01	2.959e+00
5.5	3.140e-01	3.185e+00
6.0	2.910e-01	3.436e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 14.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.175 m/s (25 %)
Current Direction : SE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	10.896
.5	315	20.0	4.774e+01	3.705e+01	22.124	5.715
1.0	630	30.0	3.214e+01	2.189e+01	12.586	3.330
1.5	945	40.1	2.413e+01	1.479e+01	8.125	2.215
2.0	1260	50.1	1.931e+01	1.076e+01	5.586	1.580
2.5	1575	60.1	1.609e+01	8.192e+00	3.973	1.177
3.0	1890	70.1	1.380e+01	6.442e+00	2.872	.902
3.5	2205	80.1	1.207e+01	5.178e+00	2.114	.712
4.0	2520	90.2	1.073e+01	4.249e+00	1.610	.586
4.5	2835	100.2	9.656e+00	3.525e+00	1.245	.495
5.0	3150	110.2	8.778e+00	2.967e+00	.983	.429
5.5	3465	120.2	8.047e+00	2.527e+00	.788	.381
6.0	3780	130.2	7.428e+00	2.161e+00	.635	.343

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
ENTRANCE CHANNEL

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 7 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	6.810e-01	1.468e+00
1.0	5.570e-01	1.795e+00
1.5	4.670e-01	2.141e+00
2.0	3.960e-01	2.525e+00
2.5	3.380e-01	2.959e+00
3.0	2.910e-01	3.436e+00
3.5	2.520e-01	3.968e+00
4.0	2.200e-01	4.545e+00
4.5	1.930e-01	5.181e+00
5.0	1.700e-01	5.882e+00
5.5	1.500e-01	6.667e+00
6.0	1.330e-01	7.519e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 7.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.075 m/s (25 %)
Current Direction : NW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	10.896
.5	135	20.0	4.774e+01	3.251e+01	19.271	5.001
1.0	270	30.0	3.214e+01	1.790e+01	10.079	2.704
1.5	405	40.1	2.413e+01	1.127e+01	5.909	1.661
2.0	540	50.1	1.931e+01	7.648e+00	3.630	1.091
2.5	675	60.1	1.609e+01	5.440e+00	2.263	.749
3.0	810	70.1	1.380e+01	4.014e+00	1.489	.556
3.5	945	80.1	1.207e+01	3.042e+00	1.017	.438
4.0	1080	90.2	1.073e+01	2.360e+00	.717	.363
4.5	1215	100.2	9.656e+00	1.864e+00	.518	.313
5.0	1350	110.2	8.778e+00	1.492e+00	.382	.279
5.5	1485	120.2	8.047e+00	1.207e+00	.285	.255
6.0	1620	130.2	7.428e+00	9.879e-01	.216	.238

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
ENTRANCE CHANNEL

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 7 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	6.810e-01	1.468e+00
1.0	5.570e-01	1.795e+00
1.5	4.670e-01	2.141e+00
2.0	3.950e-01	2.525e+00
2.5	3.380e-01	2.959e+00
3.0	2.910e-01	3.436e+00
3.5	2.520e-01	3.968e+00
4.0	2.200e-01	4.545e+00
4.5	1.930e-01	5.181e+00
5.0	1.700e-01	5.882e+00
5.5	1.500e-01	6.667e+00
6.0	1.330e-01	7.519e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 7.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.075 m/s (25 %)
Current Direction : NNW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	10.896
.5	135	20.0	4.774e+01	3.251e+01	19.271	5.001
1.0	270	30.0	3.214e+01	1.790e+01	10.079	2.704
1.5	405	40.1	2.413e+01	1.127e+01	5.909	1.661
2.0	540	50.1	1.931e+01	7.648e+00	3.630	1.091
2.5	675	60.1	1.609e+01	5.440e+00	2.263	.749
3.0	810	70.1	1.380e+01	4.014e+00	1.489	.556
3.5	945	80.1	1.207e+01	3.042e+00	1.017	.438
4.0	1080	90.2	1.073e+01	2.360e+00	.717	.363
4.5	1215	100.2	9.656e+00	1.864e+00	.518	.313
5.0	1350	110.2	8.778e+00	1.492e+00	.382	.279
5.5	1485	120.2	8.047e+00	1.207e+00	.285	.255
6.0	1620	130.2	7.428e+00	9.879e-01	.216	.238

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
ENTRANCE CHANNEL

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 7 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	6.810e-01	1.468e+00
1.0	5.570e-01	1.795e+00
1.5	4.670e-01	2.141e+00
2.0	3.960e-01	2.525e+00
2.5	3.380e-01	2.959e+00
3.0	2.910e-01	3.436e+00
3.5	2.520e-01	3.968e+00
4.0	2.200e-01	4.545e+00
4.5	1.930e-01	5.181e+00
5.0	1.700e-01	5.882e+00
5.5	1.500e-01	6.667e+00
6.0	1.330e-01	7.519e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 7.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.175 m/s (25 %)
Current Direction : SSE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	10.896
.5	315	20.0	4.774e+01	3.251e+01	19.271	5.001
1.0	630	30.0	3.214e+01	1.790e+01	10.079	2.704
1.5	945	40.1	2.413e+01	1.127e+01	5.909	1.661
2.0	1260	50.1	1.931e+01	7.648e+00	3.630	1.091
2.5	1575	60.1	1.609e+01	5.440e+00	2.263	.749
3.0	1890	70.1	1.380e+01	4.014e+00	1.489	.556
3.5	2205	80.1	1.207e+01	3.042e+00	1.017	.438
4.0	2520	90.2	1.073e+01	2.360e+00	.717	.363
4.5	2835	100.2	9.656e+00	1.864e+00	.518	.313
5.0	3150	110.2	8.778e+00	1.492e+00	.382	.279
5.5	3465	120.2	8.047e+00	1.207e+00	.285	.255
6.0	3780	130.2	7.428e+00	9.879e-01	.216	.238

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
ENTRANCE CHANNEL

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 7 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	6.810e-01	1.468e+00
1.0	5.570e-01	1.795e+00
1.5	4.670e-01	2.141e+00
2.0	3.960e-01	2.525e+00
2.5	3.380e-01	2.959e+00
3.0	2.910e-01	3.436e+00
3.5	2.520e-01	3.968e+00
4.0	2.200e-01	4.545e+00
4.5	1.930e-01	5.181e+00
5.0	1.700e-01	5.882e+00
5.5	1.500e-01	6.667e+00
6.0	1.330e-01	7.519e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 7.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.175 m/s (25 %)
Current Direction : SE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.000
Initial Diffusion Coeff. (Ko) : 16.7 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width- (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	10.896
.5	315	20.0	4.774e+01	3.251e+01	19.271	5.001
1.0	630	30.0	3.214e+01	1.790e+01	10.079	2.704
1.5	945	40.1	2.413e+01	1.127e+01	5.909	1.661
2.0	1260	50.1	1.931e+01	7.648e+00	3.630	1.091
2.5	1575	60.1	1.609e+01	5.440e+00	2.263	.749
3.0	1890	70.1	1.380e+01	4.014e+00	1.489	.556
3.5	2205	80.1	1.207e+01	3.042e+00	1.017	.438
4.0	2520	90.2	1.073e+01	2.360e+00	.717	.363
4.5	2835	100.2	9.656e+00	1.864e+00	.518	.313
5.0	3150	110.2	8.778e+00	1.492e+00	.382	.279
5.5	3465	120.2	8.047e+00	1.207e+00	.285	.255
6.0	3780	130.2	7.428e+00	9.879e-01	.216	.238

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
ENTRANCE CHANNEL

Initial Plume Width (B) : 50 m
Depth of the Plume (H) : 14 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	9.140e-01	1.094e+00
1.0	8.380e-01	1.193e+00
1.5	7.700e-01	1.299e+00
2.0	7.100e-01	1.408e+00
2.5	6.550e-01	1.527e+00
3.0	6.070e-01	1.647e+00
3.5	5.600e-01	1.786e+00
4.0	5.200e-01	1.923e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 10.000 mg/l
Depth of Water Column (h) : 14.00 m
Initial Plume Width (B) : 50 m
Current Speed (U) and Frequency : 0.029 m/s (2.2 %)
Current Direction : N
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.330
Initial Diffusion Coeff. (Ko) : 303.631 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	50.0	1.000e+01	1.000e+01	5.110	.231
.5	52	90.5	7.490e+00	6.846e+00	3.126	.187
1.0	104	138.2	4.984e+00	4.177e+00	1.573	.153
1.5	157	192.2	3.593e+00	2.767e+00	.892	.138
2.0	209	251.7	2.745e+00	1.949e+00	.551	.130
2.5	261	316.2	2.185e+00	1.431e+00	.360	.126
3.0	313	385.5	1.792e+00	1.088e+00	.247	.124
3.5	365	459.1	1.505e+00	8.428e-01	.174	.122
4.0	418	536.9	1.287e+00	6.692e-01	.127	.121

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
ENTRANCE CHANNEL

Initial Plume Width (B) : 50 m
Depth of the Plume (H) : 14 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	9.140e-01	1.094e+00
1.0	8.380e-01	1.193e+00
1.5	7.700e-01	1.299e+00
2.0	7.100e-01	1.408e+00
2.5	6.550e-01	1.527e+00
3.0	6.070e-01	1.647e+00
3.5	5.600e-01	1.786e+00
4.0	5.200e-01	1.923e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 10.000 mg/l
Depth of Water Column (h) : 14.00 m
Initial Plume Width (B) : 50 m
Current Speed (U) and Frequency : 0.030 m/s (3.4 %)
Current Direction : NNE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.330
Initial Diffusion Coeff. (Ko) : 303.631 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	50.0	1.000e+01	1.000e+01	5.110	.291
.5	54	90.5	7.490e+00	6.846e+00	3.126	.223
1.0	108	138.2	4.984e+00	4.177e+00	1.573	.170
1.5	162	192.2	3.593e+00	2.767e+00	.892	.147
2.0	216	251.7	2.745e+00	1.949e+00	.551	.136
2.5	270	316.2	2.185e+00	1.431e+00	.360	.129
3.0	324	385.5	1.792e+00	1.088e+00	.247	.125
3.5	378	459.1	1.505e+00	8.428e-01	.174	.123
4.0	432	536.9	1.287e+00	6.692e-01	.127	.121

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
ENTRANCE CHANNEL

Initial Plume Width (B) : 50 m
Depth of the Plume (H) : 14 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	9.140e-01	1.094e+00
1.0	8.380e-01	1.193e+00
1.5	7.700e-01	1.299e+00
2.0	7.100e-01	1.408e+00
2.5	6.550e-01	1.527e+00
3.0	6.070e-01	1.647e+00
3.5	5.600e-01	1.786e+00
4.0	5.200e-01	1.923e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 10.000 mg/l
Depth of Water Column (h) : 14.00 m
Initial Plume Width (B) : 50 m
Current Speed (U) and Frequency : 0.047 m/s (5.2 %)
Current Direction : NE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.330
Initial Diffusion Coeff. (Ko) : 303.631 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	50.0	1.000e+01	1.000e+01	5.110	.380
.5	85	90.5	7.490e+00	6.846e+00	3.126	.277
1.0	169	138.2	4.984e+00	4.177e+00	1.573	.196
1.5	254	192.2	3.593e+00	2.767e+00	.892	.161
2.0	338	251.7	2.745e+00	1.949e+00	.551	.143
2.5	423	316.2	2.185e+00	1.431e+00	.360	.133
3.0	508	385.5	1.792e+00	1.088e+00	.247	.128
3.5	592	459.1	1.505e+00	8.428e-01	.174	.124
4.0	677	536.9	1.287e+00	6.692e-01	.127	.121

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
ENTRANCE CHANNEL

Initial Plume Width (B) : 50 m
Depth of the Plume (H) : 14 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	9.140e-01	1.094e+00
1.0	8.380e-01	1.193e+00
1.5	7.700e-01	1.299e+00
2.0	7.100e-01	1.408e+00
2.5	6.550e-01	1.527e+00
3.0	6.070e-01	1.647e+00
3.5	5.600e-01	1.786e+00
4.0	5.200e-01	1.923e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 10.000 mg/l
Depth of Water Column (h) : 14.00 m
Initial Plume Width (B) : 50 m
Current Speed (U) and Frequency : 0.09[illegible] m/s (12.5 %)
Current Direction : ENE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.330
Initial Diffusion Coeff. (Ko) : 303.631 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	50.0	1.000e+01	1.000e+01	5.110	.745
.5	164	90.5	7.490e+00	6.846e+00	3.126	.497
1.0	328	138.2	4.984e+00	4.177e+00	1.573	.302
1.5	491	192.2	3.593e+00	2.767e+00	.892	.217
2.0	655	251.7	2.745e+00	1.949e+00	.551	.175
2.5	819	316.2	2.185e+00	1.431e+00	.360	.151
3.0	983	385.5	1.792e+00	1.088e+00	.247	.137
3.5	1147	459.1	1.505e+00	8.428e-01	.174	.128
4.0	1310	536.9	1.287e+00	6.692e-01	.127	.122

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
ENTRANCE CHANNEL

Initial Plume Width (B) : 50 m
Depth of the Plume (H) : 14 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	9.140e-01	1.094e+00
1.0	8.380e-01	1.193e+00
1.5	7.700e-01	1.299e+00
2.0	7.100e-01	1.408e+00
2.5	6.550e-01	1.527e+00
3.0	6.070e-01	1.647e+00
3.5	5.600e-01	1.786e+00
4.0	5.200e-01	1.923e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 10.000 mg/l
Depth of Water Column (h) : 14.00 m
Initial Plume Width (B) : 50 m
Current Speed (U) and Frequency : 0.116 m/s (13.2 %)
Current Direction : E
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.330
Initial Diffusion Coeff. (Ko) : 303.631 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	50.0	1.000e+01	1.000e+01	5.110	.780
.5	209	90.5	7.490e+00	6.846e+00	3.126	.518
1.0	418	138.2	4.984e+00	4.177e+00	1.573	.313
1.5	626	192.2	3.593e+00	2.767e+00	.892	.223
2.0	835	251.7	2.745e+00	1.949e+00	.551	.178
2.5	1044	316.2	2.185e+00	1.431e+00	.360	.153
3.0	1253	385.5	1.792e+00	1.088e+00	.247	.138
3.5	1462	459.1	1.505e+00	8.428e-01	.174	.128
4.0	1670	536.9	1.287e+00	6.692e-01	.127	.122

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
ENTRANCE CHANNEL

Initial Plume Width (B) : 50 m
Depth of the Plume (H) : 14 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	9.140e-01	1.094e+00
1.0	8.380e-01	1.193e+00
1.5	7.700e-01	1.299e+00
2.0	7.100e-01	1.408e+00
2.5	6.550e-01	1.527e+00
3.0	6.070e-01	1.647e+00
3.5	5.600e-01	1.786e+00
4.0	5.200e-01	1.923e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 10.000 mg/l
Depth of Water Column (h) : 14.00 m
Initial Plume Width (B) : 50 m
Current Speed (U) and Frequency : 0.084 m/s (4.6 %)
Current Direction : ESE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.330
Initial Diffusion Coeff. (Ko) : 303.631 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	50.0	1.000e+01	1.000e+01	5.110	.350
.5	151	90.5	7.490e+00	6.846e+00	3.126	.259
1.0	302	138.2	4.984e+00	4.177e+00	1.573	.188
1.5	454	192.2	3.593e+00	2.767e+00	.892	.156
2.0	605	251.7	2.745e+00	1.949e+00	.551	.141
2.5	756	316.2	2.185e+00	1.431e+00	.360	.132
3.0	907	385.5	1.792e+00	1.088e+00	.247	.127
3.5	1058	459.1	1.505e+00	8.428e-01	.174	.123
4.0	1210	536.9	1.287e+00	6.692e-01	.127	.121

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
ENTRANCE CHANNEL

Initial Plume Width (B) : 50 m
Depth of the Plume (H) : 14 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	9.140e-01	1.094e+00
1.0	8.380e-01	1.193e+00
1.5	7.700e-01	1.299e+00
2.0	7.100e-01	1.408e+00
2.5	6.550e-01	1.527e+00
3.0	6.070e-01	1.647e+00
3.5	5.600e-01	1.786e+00
4.0	5.200e-01	1.923e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 10.000 mg/l
Depth of Water Column (h) : 14.00 m
Initial Plume Width (B) : 50 m
Current Speed (U) and Frequency : 0.049 m/s (1.8 %)
Current Direction : SE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.330
Initial Diffusion Coeff. (Ko) : 303.631 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	50.0	1.000e+01	1.000e+01	5.110	.211
.5	88	90.5	7.490e+00	6.846e+00	3.126	.175
1.0	176	138.2	4.984e+00	4.177e+00	1.573	.147
1.5	265	192.2	3.593e+00	2.767e+00	.892	.135
2.0	353	251.7	2.745e+00	1.949e+00	.551	.129
2.5	441	316.2	2.185e+00	1.431e+00	.360	.125
3.0	529	385.5	1.792e+00	1.088e+00	.247	.123
3.5	617	459.1	1.505e+00	8.428e-01	.174	.122
4.0	706	536.9	1.287e+00	6.692e-01	.127	.121

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
ENTRANCE CHANNEL

Initial Plume Width (B) : 50 m
Depth of the Plume (H) : 14 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	9.140e-01	1.094e+00
1.0	8.380e-01	1.193e+00
1.5	7.700e-01	1.299e+00
2.0	7.100e-01	1.408e+00
2.5	6.550e-01	1.527e+00
3.0	6.070e-01	1.647e+00
3.5	5.600e-01	1.786e+00
4.0	5.200e-01	1.923e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 10.000 mg/l
Depth of Water Column (h) : 14.00 m
Initial Plume Width (B) : 50 m
Current Speed (U) and Frequency : 0.027 m/s (.9 %)
Current Direction : S
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.330
Initial Diffusion Coeff. (Ko) : 303.631 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	50.0	1.000e+01	1.000e+01	5.110	.166
.5	49	90.5	7.490e+00	6.846e+00	3.126	.148
1.0	97	138.2	4.984e+00	4.177e+00	1.573	.134
1.5	146	192.2	3.593e+00	2.767e+00	.892	.128
2.0	194	251.7	2.745e+00	1.949e+00	.551	.125
2.5	243	316.2	2.185e+00	1.431e+00	.360	.123
3.0	292	385.5	1.792e+00	1.088e+00	.247	.122
3.5	340	459.1	1.505e+00	8.428e-01	.174	.121
4.0	389	536.9	1.287e+00	6.692e-01	.127	.121

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
ENTRANCE CHANNEL

Initial Plume Width (B) : 50 m
Depth of the Plume (H) : 14 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	9.140e-01	1.094e+00
1.0	8.380e-01	1.193e+00
1.5	7.700e-01	1.299e+00
2.0	7.100e-01	1.408e+00
2.5	6.550e-01	1.527e+00
3.0	6.070e-01	1.647e+00
3.5	5.600e-01	1.786e+00
4.0	5.200e-01	1.923e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 10.000 mg/l
Depth of Water Column (h) : 14.00 m
Initial Plume Width (B) : 50 m
Current Speed (U) and Frequency : 0.026 m/s (1.6 %)
Current Direction : SSW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.330
Initial Diffusion Coeff. (Ko) : 303.631 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	50.0	1.000e+01	1.000e+01	5.110	.201
.5	47	90.5	7.490e+00	6.846e+00	3.126	.169
1.0	94	138.2	4.984e+00	4.177e+00	1.573	.144
1.5	140	192.2	3.593e+00	2.767e+00	.892	.133
2.0	187	251.7	2.745e+00	1.949e+00	.551	.128
2.5	234	316.2	2.185e+00	1.431e+00	.360	.125
3.0	281	385.5	1.792e+00	1.088e+00	.247	.123
3.5	328	459.1	1.505e+00	8.428e-01	.174	.122
4.0	374	536.9	1.287e+00	6.692e-01	.127	.121

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
ENTRANCE CHANNEL

Initial Plume Width (B) : 50 m
Depth of the Plume (H) : 14 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	9.140e-01	1.094e+00
1.0	8.380e-01	1.193e+00
1.5	7.700e-01	1.299e+00
2.0	7.100e-01	1.408e+00
2.5	6.550e-01	1.527e+00
3.0	6.070e-01	1.647e+00
3.5	5.600e-01	1.786e+00
4.0	5.200e-01	1.923e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 10.000 mg/l
Depth of Water Column (h) : 14.00 m
Initial Plume Width (B) : 50 m
Current Speed (U) and Frequency : 0.044 m/s (2.2 %)
Current Direction : SW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.330
Initial Diffusion Coeff. (Ko) : 303.631 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	50.0	1.000e+01	1.000e+01	5.110	.231
.5	79	90.5	7.490e+00	6.846e+00	3.126	.187
1.0	158	138.2	4.984e+00	4.177e+00	1.573	.153
1.5	238	192.2	3.593e+00	2.767e+00	.892	.138
2.0	317	251.7	2.745e+00	1.949e+00	.551	.130
2.5	396	316.2	2.185e+00	1.431e+00	.360	.126
3.0	475	385.5	1.792e+00	1.088e+00	.247	.124
3.5	554	459.1	1.505e+00	8.428e-01	.174	.122
4.0	634	536.9	1.287e+00	6.692e-01	.127	.121

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
ENTRANCE CHANNEL

Initial Plume Width (B) : 50 m
Depth of the Plume (H) : 14 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	9.140e-01	1.094e+00
1.0	8.380e-01	1.193e+00
1.5	7.700e-01	1.299e+00
2.0	7.100e-01	1.408e+00
2.5	6.550e-01	1.527e+00
3.0	6.070e-01	1.647e+00
3.5	5.600e-01	1.786e+00
4.0	5.200e-01	1.923e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 10.000 mg/l
Depth of Water Column (h) : 14.00 m
Initial Plume Width (B) : 50 m
Current Speed (U) and Frequency : 0.093 m/s (6.9 %)
Current Direction : WSW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.330
Initial Diffusion Coeff. (Ko) : 303.631 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	50.0	1.000e+01	1.000e+01	5.110	.465
.5	167	90.5	7.490e+00	6.846e+00	3.126	.328
1.0	335	138.2	4.984e+00	4.177e+00	1.573	.221
1.5	502	192.2	3.593e+00	2.767e+00	.892	.174
2.0	670	251.7	2.745e+00	1.949e+00	.551	.151
2.5	837	316.2	2.185e+00	1.431e+00	.360	.138
3.0	1004	385.5	1.792e+00	1.088e+00	.247	.130
3.5	1172	459.1	1.505e+00	8.428e-01	.174	.125
4.0	1339	536.9	1.287e+00	6.692e-01	.127	.121

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
ENTRANCE CHANNEL

Initial Plume Width (B) : 50 m
Depth of the Plume (H) : 14 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	9.140e-01	1.094e+00
1.0	8.380e-01	1.193e+00
1.5	7.700e-01	1.299e+00
2.0	7.100e-01	1.408e+00
2.5	6.550e-01	1.527e+00
3.0	6.070e-01	1.647e+00
3.5	5.600e-01	1.786e+00
4.0	5.200e-01	1.923e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 10.000 mg/l
Depth of Water Column (h) : 14.00 m
Initial Plume Width (B) : 50 m
Current Speed (U) and Frequency : 0.154 m/s (26.8 %)
Current Direction : W
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.330
Initial Diffusion Coeff. (Ko) : 303.631 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	50.0	1.000e+01	1.000e+01	5.110	1.458
.5	277	90.5	7.490e+00	6.846e+00	3.126	.926
1.0	554	138.2	4.984e+00	4.177e+00	1.573	.510
1.5	832	192.2	3.593e+00	2.767e+00	.892	.328
2.0	1109	251.7	2.745e+00	1.949e+00	.551	.236
2.5	1386	316.2	2.185e+00	1.431e+00	.360	.185
3.0	1663	385.5	1.792e+00	1.088e+00	.247	.155
3.5	1940	459.1	1.505e+00	8.428e-01	.174	.135
4.0	2218	536.9	1.287e+00	6.692e-01	.127	.122

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
ENTRANCE CHANNEL

Initial Plume Width (B) : 50 m
Depth of the Plume (H) : 14 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	9.140e-01	1.094e+00
1.0	8.380e-01	1.193e+00
1.5	7.700e-01	1.299e+00
2.0	7.100e-01	1.408e+00
2.5	6.550e-01	1.527e+00
3.0	6.070e-01	1.647e+00
3.5	5.600e-01	1.786e+00
4.0	5.200e-01	1.923e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 10.000 mg/l
Depth of Water Column (h) : 14.00 m
Initial Plume Width (B) : 50 m
Current Speed (U) and Frequency : 0.075 m/s (10.4 %)
Current Direction : WNW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.330
Initial Diffusion Coeff. (Ko) : 303.631 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	50.0	1.000e+01	1.000e+01	5.110	.640
.5	135	90.5	7.490e+00	6.846e+00	3.126	.434
1.0	270	138.2	4.984e+00	4.177e+00	1.573	.272
1.5	405	192.2	3.593e+00	2.767e+00	.892	.201
2.0	540	251.7	2.745e+00	1.949e+00	.551	.166
2.5	675	316.2	2.185e+00	1.431e+00	.360	.146
3.0	810	385.5	1.792e+00	1.088e+00	.247	.134
3.5	945	459.1	1.505e+00	8.428e-01	.174	.126
4.0	1080	536.9	1.287e+00	6.692e-01	.127	.122

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
ENTRANCE CHANNEL

Initial Plume Width (B) : 50 m
Depth of the Plume (H) : 14 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	9.140e-01	1.094e+00
1.0	8.380e-01	1.193e+00
1.5	7.700e-01	1.299e+00
2.0	7.100e-01	1.408e+00
2.5	6.550e-01	1.527e+00
3.0	6.070e-01	1.647e+00
3.5	5.600e-01	1.786e+00
4.0	5.200e-01	1.923e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 10.000 mg/l
Depth of Water Column (h) : 14.00 m
Initial Plume Width (B) : 50 m
Current Speed (U) and Frequency : 0.037 m/s (4.1 %)
Current Direction : NW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.330
Initial Diffusion Coeff. (Ko) : 303.631 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	50.0	1.000e+01	1.000e+01	5.110	.326
.5	67	90.5	7.490e+00	6.846e+00	3.126	.244
1.0	133	138.2	4.984e+00	4.177e+00	1.573	.181
1.5	200	192.2	3.593e+00	2.767e+00	.892	.153
2.0	266	251.7	2.745e+00	1.949e+00	.551	.139
2.5	333	316.2	2.185e+00	1.431e+00	.360	.131
3.0	400	385.5	1.792e+00	1.088e+00	.247	.126
3.5	466	459.1	1.505e+00	8.428e-01	.174	.123
4.0	533	536.9	1.287e+00	6.692e-01	.127	.121

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
ENTRANCE CHANNEL

Initial Plume Width (B) : 50 m
Depth of the Plume (H) : 14 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	9.140e-01	1.094e+00
1.0	8.380e-01	1.193e+00
1.5	7.700e-01	1.299e+00
2.0	7.100e-01	1.408e+00
2.5	6.550e-01	1.527e+00
3.0	6.070e-01	1.647e+00
3.5	5.600e-01	1.786e+00
4.0	5.200e-01	1.923e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
REEF FLAT

Initial Sediment Concentration (Ci): 10.000 mg/l
Depth of Water Column (h) : 14.00 m
Initial Plume Width (B) : 50 m
Current Speed (U) and Frequency : 0.026 m/s (2.9 %)
Current Direction : NNW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.330
Initial Diffusion Coeff. (Ko) : 303.631 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	50.0	1.000e+01	1.000e+01	5.110	.266
.5	47	90.5	7.490e+00	6.846e+00	3.126	.208
1.0	94	138.2	4.984e+00	4.177e+00	1.573	.163
1.5	140	192.2	3.593e+00	2.767e+00	.892	.143
2.0	187	251.7	2.745e+00	1.949e+00	.551	.133
2.5	234	316.2	2.185e+00	1.431e+00	.360	.128
3.0	281	385.5	1.792e+00	1.088e+00	.247	.125
3.5	328	459.1	1.505e+00	8.428e-01	.174	.123
4.0	374	536.9	1.287e+00	6.692e-01	.127	.121

APPENDIX A-3

Coral Zone

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
CORAL ZONE INSHORE, PLUME DEPTH=16m

Time (hours)	Relative Concentration Decrease Per Grain Size Fraction (mm) (weight percent listed below grain size)										
	.210	.150	.110	.074	.053	.037	.026	.019	.013	.009	all (mm)
	.020	.050	.070	.040	.030	.150	.400	.200	.020	.020	(wt %)
.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
.5	.041	.110	.235	.519	.714	.849	.922	.958	.980	.990	.792
1.0	.002	.012	.055	.269	.510	.721	.851	.917	.960	.981	.701
1.5	.000	.001	.013	.140	.365	.612	.784	.878	.941	.971	.637
2.0	.000	.000	.003	.073	.260	.519	.723	.841	.922	.962	.584
2.5	.000	.000	.001	.038	.186	.441	.667	.806	.904	.953	.538
3.0	.000	.000	.000	.020	.133	.374	.615	.772	.886	.943	.498
3.5	.000	.000	.000	.010	.095	.317	.567	.739	.868	.934	.462
4.0	.000	.000	.000	.005	.068	.269	.523	.708	.851	.925	.429
4.5	.000	.000	.000	.003	.048	.229	.483	.678	.834	.916	.400
5.0	.000	.000	.000	.001	.035	.194	.445	.649	.817	.908	.373
5.5	.000	.000	.000	.001	.025	.165	.411	.622	.800	.899	.348
6.0	.000	.000	.000	.000	.018	.140	.379	.595	.784	.890	.326
6.5	.000	.000	.000	.000	.013	.119	.349	.570	.769	.882	.305
7.0	.000	.000	.000	.000	.009	.101	.322	.546	.753	.873	.286
7.5	.000	.000	.000	.000	.006	.086	.297	.523	.738	.865	.268
8.0	.000	.000	.000	.000	.005	.073	.274	.501	.723	.856	.252

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
CORAL ZONE INSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 16 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	7.920e-01	1.263e+00
1.0	7.010e-01	1.427e+00
1.5	6.370e-01	1.570e+00
2.0	5.840e-01	1.712e+00
2.5	5.380e-01	1.859e+00
3.0	4.980e-01	2.008e+00
3.5	4.620e-01	2.165e+00
4.0	4.290e-01	2.331e+00
4.5	4.000e-01	2.500e+00
5.0	3.730e-01	2.681e+00
5.5	3.480e-01	2.874e+00
6.0	3.260e-01	3.067e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
CORAL ZONE INSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 16.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.029 m/s (2.2 %)
Current Direction : N
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	1.061
.5	52	38.1	2.538e+01	2.010e+01	11.462	.371
1.0	104	76.4	1.267e+01	8.879e+00	4.405	.215
1.5	157	122.6	7.891e+00	5.026e+00	2.029	.163
2.0	209	175.6	5.509e+00	3.217e+00	1.098	.143
2.5	261	234.6	4.124e+00	2.219e+00	.659	.133
3.0	313	299.0	3.235e+00	1.611e+00	.424	.128
3.5	365	368.4	2.626e+00	1.213e+00	.287	.125
4.0	418	442.5	2.186e+00	9.378e-01	.201	.123
4.5	470	521.0	1.857e+00	7.427e-01	.146	.122
5.0	522	603.7	1.602e+00	5.977e-01	.108	.121
5.5	574	690.3	1.401e+00	4.877e-01	.082	.120
6.0	626	780.7	1.239e+00	4.039e-01	.063	.120

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
CORAL ZONE INSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 16 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	7.920e-01	1.263e+00
1.0	7.010e-01	1.427e+00
1.5	6.370e-01	1.570e+00
2.0	5.840e-01	1.712e+00
2.5	5.380e-01	1.859e+00
3.0	4.980e-01	2.008e+00
3.5	4.620e-01	2.165e+00
4.0	4.290e-01	2.331e+00
4.5	4.000e-01	2.500e+00
5.0	3.730e-01	2.681e+00
5.5	3.480e-01	2.874e+00
6.0	3.260e-01	3.067e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
CORAL ZONE INSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 16.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.030 m/s (3.4 %)
Current Direction : NNE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	1.574
.5	54	38.1	2.538e+01	2.010e+01	11.462	.507
1.0	108	76.4	1.267e+01	8.879e+00	4.405	.267
1.5	162	122.6	7.891e+00	5.026e+00	2.029	.186
2.0	216	175.6	5.509e+00	3.217e+00	1.098	.154
2.5	270	234.6	4.124e+00	2.219e+00	.659	.139
3.0	324	299.0	3.235e+00	1.611e+00	.424	.131
3.5	378	368.4	2.626e+00	1.213e+00	.287	.127
4.0	432	442.5	2.186e+00	9.378e-01	.201	.124
4.5	486	521.0	1.857e+00	7.427e-01	.146	.122
5.0	540	603.7	1.602e+00	5.977e-01	.108	.121
5.5	594	690.3	1.401e+00	4.877e-01	.082	.120
6.0	648	780.7	1.239e+00	4.039e-01	.063	.119

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
CORAL ZONE INSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 16 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	7.920e-01	1.263e+00
1.0	7.010e-01	1.427e+00
1.5	6.370e-01	1.570e+00
2.0	5.840e-01	1.712e+00
2.5	5.380e-01	1.859e+00
3.0	4.980e-01	2.008e+00
3.5	4.620e-01	2.165e+00
4.0	4.290e-01	2.331e+00
4.5	4.000e-01	2.500e+00
5.0	3.730e-01	2.681e+00
5.5	3.480e-01	2.874e+00
6.0	3.260e-01	3.067e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
CORAL ZONE INSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 16.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.047 m/s (5.2 %)
Current Direction : NE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763' (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	2.343
.5	85	38.1	2.538e+01	2.010e+01	11.462	.711
1.0	169	76.4	1.267e+01	8.879e+00	4.405	.344
1.5	254	122.6	7.891e+00	5.026e+00	2.029	.220
2.0	338	175.6	5.509e+00	3.217e+00	1.098	.172
2.5	423	234.6	4.124e+00	2.219e+00	.659	.149
3.0	508	299.0	3.235e+00	1.611e+00	.424	.137
3.5	592	368.4	2.626e+00	1.213e+00	.287	.130
4.0	677	442.5	2.186e+00	9.378e-01	.201	.125
4.5	761	521.0	1.857e+00	7.427e-01	.146	.122
5.0	846	603.7	1.602e+00	5.977e-01	.108	.120
5.5	931	690.3	1.401e+00	4.877e-01	.082	.119
6.0	1015	780.7	1.239e+00	4.039e-01	.063	.118

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
CORAL ZONE INSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 16 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	7.920e-01	1.263e+00
1.0	7.010e-01	1.427e+00
1.5	6.370e-01	1.570e+00
2.0	5.840e-01	1.712e+00
2.5	5.380e-01	1.859e+00
3.0	4.980e-01	2.008e+00
3.5	4.620e-01	2.165e+00
4.0	4.290e-01	2.331e+00
4.5	4.000e-01	2.500e+00
5.0	3.730e-01	2.681e+00
5.5	3.480e-01	2.874e+00
6.0	3.260e-01	3.067e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
CORAL ZONE INSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 16.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.091 m/s (12.5 %)
Current Direction : ENE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	5.462
.5	164	38.1	2.538e+01	2.010e+01	11.462	1.539
1.0	328	76.4	1.267e+01	8.879e+00	4.405	.657
1.5	491	122.6	7.891e+00	5.026e+00	2.029	.360
2.0	655	175.6	5.509e+00	3.217e+00	1.098	.243
2.5	819	234.6	4.124e+00	2.219e+00	.659	.188
3.0	983	299.0	3.235e+00	1.611e+00	.424	.159
3.5	1147	368.4	2.626e+00	1.213e+00	.287	.142
4.0	1310	442.5	2.186e+00	9.378e-01	.201	.131
4.5	1474	521.0	1.857e+00	7.427e-01	.146	.124
5.0	1638	603.7	1.602e+00	5.977e-01	.108	.119
5.5	1802	690.3	1.401e+00	4.877e-01	.082	.116
6.0	1966	780.7	1.239e+00	4.039e-01	.063	.114

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
CORAL ZONE INSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 16 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	7.920e-01	1.263e+00
1.0	7.010e-01	1.427e+00
1.5	6.370e-01	1.570e+00
2.0	5.840e-01	1.712e+00
2.5	5.380e-01	1.859e+00
3.0	4.980e-01	2.008e+00
3.5	4.620e-01	2.165e+00
4.0	4.290e-01	2.331e+00
4.5	4.000e-01	2.500e+00
5.0	3.730e-01	2.681e+00
5.5	3.480e-01	2.874e+00
6.0	3.260e-01	3.067e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
CORAL ZONE INSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 16.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.116 m/s (13.2 %)
Current Direction : E
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	5.761
.5	209	38.1	2.538e+01	2.010e+01	11.462	1.618
1.0	418	76.4	1.267e+01	8.879e+00	4.405	.687
1.5	626	122.6	7.891e+00	5.026e+00	2.029	.373
2.0	835	175.6	5.509e+00	3.217e+00	1.098	.250
2.5	1044	234.6	4.124e+00	2.219e+00	.659	.192
3.0	1253	299.0	3.235e+00	1.611e+00	.424	.161
3.5	1462	368.4	2.626e+00	1.213e+00	.287	.143
4.0	1670	442.5	2.186e+00	9.378e-01	.201	.132
4.5	1879	521.0	1.857e+00	7.427e-01	.146	.124
5.0	2088	603.7	1.602e+00	5.977e-01	.108	.119
5.5	2297	690.3	1.401e+00	4.877e-01	.082	.116
6.0	2506	780.7	1.239e+00	4.039e-01	.063	.113

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
CORAL ZONE INSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 16 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	7.920e-01	1.263e+00
1.0	7.010e-01	1.427e+00
1.5	6.370e-01	1.570e+00
2.0	5.840e-01	1.712e+00
2.5	5.380e-01	1.859e+00
3.0	4.980e-01	2.008e+00
3.5	4.620e-01	2.165e+00
4.0	4.290e-01	2.331e+00
4.5	4.000e-01	2.500e+00
5.0	3.730e-01	2.681e+00
5.5	3.480e-01	2.874e+00
6.0	3.260e-01	3.067e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
CORAL ZONE INSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 16.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.084 m/s (4.6 %)
Current Direction : ESE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	2.087
.5	151	38.1	2.538e+01	2.010e+01	11.462	.643
1.0	302	76.4	1.267e+01	8.879e+00	4.405	.318
1.5	454	122.6	7.891e+00	5.026e+00	2.029	.209
2.0	605	175.6	5.509e+00	3.217e+00	1.098	.166
2.5	756	234.6	4.124e+00	2.219e+00	.659	.146
3.0	907	299.0	3.235e+00	1.611e+00	.424	.135
3.5	1058	368.4	2.626e+00	1.213e+00	.287	.129
4.0	1210	442.5	2.186e+00	9.378e-01	.201	.125
4.5	1361	521.0	1.857e+00	7.427e-01	.146	.122
5.0	1512	603.7	1.602e+00	5.977e-01	.108	.120
5.5	1663	690.3	1.401e+00	4.877e-01	.082	.119
6.0	1814	780.7	1.239e+00	4.039e-01	.063	.118

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
CORAL ZONE INSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 16 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	7.920e-01	1.263e+00
1.0	7.010e-01	1.427e+00
1.5	6.370e-01	1.570e+00
2.0	5.840e-01	1.712e+00
2.5	5.380e-01	1.859e+00
3.0	4.980e-01	2.008e+00
3.5	4.620e-01	2.165e+00
4.0	4.290e-01	2.331e+00
4.5	4.000e-01	2.500e+00
5.0	3.730e-01	2.681e+00
5.5	3.480e-01	2.874e+00
6.0	3.260e-01	3.067e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
CORAL ZONE INSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 16.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.049 m/s (1.8 %)
Current Direction : SE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	.890
.5	88	38.1	2.538e+01	2.010e+01	11.462	.325
1.0	176	76.4	1.267e+01	8.879e+00	4.405	.198
1.5	265	122.6	7.891e+00	5.026e+00	2.029	.155
2.0	353	175.6	5.509e+00	3.217e+00	1.098	.139
2.5	441	234.6	4.124e+00	2.219e+00	.659	.131
3.0	529	299.0	3.235e+00	1.611e+00	.424	.126
3.5	617	368.4	2.626e+00	1.213e+00	.287	.124
4.0	706	442.5	2.186e+00	9.378e-01	.201	.122
4.5	794	521.0	1.857e+00	7.427e-01	.146	.121
5.0	882	603.7	1.602e+00	5.977e-01	.108	.121
5.5	970	690.3	1.401e+00	4.877e-01	.082	.120
6.0	1058	780.7	1.239e+00	4.039e-01	.063	.120

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
CORAL ZONE INSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 16 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	7.920e-01	1.263e+00
1.0	7.010e-01	1.427e+00
1.5	6.370e-01	1.570e+00
2.0	5.840e-01	1.712e+00
2.5	5.380e-01	1.859e+00
3.0	4.980e-01	2.008e+00
3.5	4.620e-01	2.165e+00
4.0	4.290e-01	2.331e+00
4.5	4.000e-01	2.500e+00
5.0	3.730e-01	2.681e+00
5.5	3.480e-01	2.874e+00
6.0	3.260e-01	3.067e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
CORAL ZONE INSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 16.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.031 m/s (1.3 %)
Current Direction : SSE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	.676
.5	56	38.1	2.538e+01	2.010e+01	11.462	.268
1.0	112	76.4	1.267e+01	8.879e+00	4.405	.177
1.5	167	122.6	7.891e+00	5.026e+00	2.029	.146
2.0	223	175.6	5.509e+00	3.217e+00	1.098	.134
2.5	279	234.6	4.124e+00	2.219e+00	.659	.128
3.0	335	299.0	3.235e+00	1.611e+00	.424	.125
3.5	391	368.4	2.626e+00	1.213e+00	.287	.123
4.0	446	442.5	2.186e+00	9.378e-01	.201	.122
4.5	502	521.0	1.857e+00	7.427e-01	.146	.121
5.0	558	603.7	1.602e+00	5.977e-01	.108	.121
5.5	614	690.3	1.401e+00	4.877e-01	.082	.120
6.0	670	780.7	1.239e+00	4.039e-01	.063	.120

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
CORAL ZONE INSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 16 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	7.920e-01	1.263e+00
1.0	7.010e-01	1.427e+00
1.5	6.370e-01	1.570e+00
2.0	5.840e-01	1.712e+00
2.5	5.380e-01	1.859e+00
3.0	4.980e-01	2.008e+00
3.5	4.620e-01	2.165e+00
4.0	4.290e-01	2.331e+00
4.5	4.000e-01	2.500e+00
5.0	3.730e-01	2.681e+00
5.5	3.480e-01	2.874e+00
6.0	3.260e-01	3.067e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
CORAL ZONE INSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 16.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.027 m/s (.9 %)
Current Direction : S
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	.506
.5	49	38.1	2.538e+01	2.010e+01	11.462	.223
1.0	97	76.4	1.267e+01	8.879e+00	4.405	.160
1.5	146	122.6	7.891e+00	5.026e+00	2.029	.138
2.0	194	175.6	5.509e+00	3.217e+00	1.098	.130
2.5	243	234.6	4.124e+00	2.219e+00	.659	.126
3.0	292	299.0	3.235e+00	1.611e+00	.424	.124
3.5	340	368.4	2.626e+00	1.213e+00	.287	.122
4.0	389	442.5	2.186e+00	9.378e-01	.201	.122
4.5	437	521.0	1.857e+00	7.427e-01	.146	.121
5.0	486	603.7	1.602e+00	5.977e-01	.108	.121
5.5	535	690.3	1.401e+00	4.877e-01	.082	.121
6.0	583	780.7	1.239e+00	4.039e-01	.063	.120

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
CORAL ZONE INSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 16 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	7.920e-01	1.263e+00
1.0	7.010e-01	1.427e+00
1.5	6.370e-01	1.570e+00
2.0	5.840e-01	1.712e+00
2.5	5.380e-01	1.859e+00
3.0	4.980e-01	2.008e+00
3.5	4.620e-01	2.165e+00
4.0	4.290e-01	2.331e+00
4.5	4.000e-01	2.500e+00
5.0	3.730e-01	2.681e+00
5.5	3.480e-01	2.874e+00
6.0	3.260e-01	3.067e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
CORAL ZONE INSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 16.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.026 m/s (1.6 %)
Current Direction : SSW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	.805
.5	47	38.1	2.538e+01	2.010e+01	11.462	.302
1.0	94	76.4	1.267e+01	8.879e+00	4.405	.190
1.5	140	122.6	7.891e+00	5.026e+00	2.029	.152
2.0	187	175.6	5.509e+00	3.217e+00	1.098	.137
2.5	234	234.6	4.124e+00	2.219e+00	.659	.130
3.0	281	299.0	3.235e+00	1.611e+00	.424	.126
3.5	328	368.4	2.626e+00	1.213e+00	.287	.124
4.0	374	442.5	2.186e+00	9.378e-01	.201	.122
4.5	421	521.0	1.857e+00	7.427e-01	.146	.121
5.0	468	603.7	1.602e+00	5.977e-01	.108	.121
5.5	515	690.3	1.401e+00	4.877e-01	.082	.120
6.0	562	780.7	1.239e+00	4.039e-01	.063	.120

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
CORAL ZONE INSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 16 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	7.920e-01	1.263e+00
1.0	7.010e-01	1.427e+00
1.5	6.370e-01	1.570e+00
2.0	5.840e-01	1.712e+00
2.5	5.380e-01	1.859e+00
3.0	4.980e-01	2.008e+00
3.5	4.620e-01	2.165e+00
4.0	4.290e-01	2.331e+00
4.5	4.000e-01	2.500e+00
5.0	3.730e-01	2.681e+00
5.5	3.480e-01	2.874e+00
6.0	3.260e-01	3.067e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
CORAL ZONE INSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 16.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.044 m/s (2.2 %)
Current Direction : SW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	1.061
.5	79	38.1	2.538e+01	2.010e+01	11.462	.371
1.0	158	76.4	1.267e+01	8.879e+00	4.405	.215
1.5	238	122.6	7.891e+00	5.026e+00	2.029	.163
2.0	317	175.6	5.509e+00	3.217e+00	1.098	.143
2.5	396	234.6	4.124e+00	2.219e+00	.659	.133
3.0	475	299.0	3.235e+00	1.611e+00	.424	.128
3.5	554	368.4	2.626e+00	1.213e+00	.287	.125
4.0	634	442.5	2.186e+00	9.378e-01	.201	.123
4.5	713	521.0	1.857e+00	7.427e-01	.146	.122
5.0	792	603.7	1.602e+00	5.977e-01	.108	.121
5.5	871	690.3	1.401e+00	4.877e-01	.082	.120
6.0	950	780.7	1.239e+00	4.039e-01	.063	.120

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
CORAL ZONE INSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 16 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	7.920e-01	1.263e+00
1.0	7.010e-01	1.427e+00
1.5	6.370e-01	1.570e+00
2.0	5.840e-01	1.712e+00
2.5	5.380e-01	1.859e+00
3.0	4.980e-01	2.008e+00
3.5	4.620e-01	2.165e+00
4.0	4.290e-01	2.331e+00
4.5	4.000e-01	2.500e+00
5.0	3.730e-01	2.681e+00
5.5	3.480e-01	2.874e+00
6.0	3.260e-01	3.067e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
CORAL ZONE INSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 16.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.093 m/s (6.9 %)
Current Direction : WSW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	3.069
.5	167	38.1	2.538e+01	2.010e+01	11.462	.904
1.0	335	76.4	1.267e+01	8.879e+00	4.405	.417
1.5	502	122.6	7.891e+00	5.026e+00	2.029	.253
2.0	670	175.6	5.509e+00	3.217e+00	1.098	.188
2.5	837	234.6	4.124e+00	2.219e+00	.659	.158
3.0	1004	299.0	3.235e+00	1.611e+00	.424	.142
3.5	1172	368.4	2.626e+00	1.213e+00	.287	.132
4.0	1339	442.5	2.186e+00	9.378e-01	.201	.127
4.5	1507	521.0	1.857e+00	7.427e-01	.146	.123
5.0	1674	603.7	1.602e+00	5.977e-01	.108	.120
5.5	1841	690.3	1.401e+00	4.877e-01	.082	.118
6.0	2009	780.7	1.239e+00	4.039e-01	.063	.117

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
CORAL ZONE INSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 16 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	7.920e-01	1.263e+00
1.0	7.010e-01	1.427e+00
1.5	6.370e-01	1.570e+00
2.0	5.840e-01	1.712e+00
2.5	5.380e-01	1.859e+00
3.0	4.980e-01	2.008e+00
3.5	4.620e-01	2.165e+00
4.0	4.290e-01	2.331e+00
4.5	4.000e-01	2.500e+00
5.0	3.730e-01	2.681e+00
5.5	3.480e-01	2.874e+00
6.0	3.260e-01	3.067e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
CORAL ZONE INSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 16.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.154 m/s (26.8 %)
Current Direction : W
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	11.572
.5	277	38.1	2.538e+01	2.010e+01	11.462	3.160
1.0	554	76.4	1.267e+01	8.879e+00	4.405	1.269
1.5	832	122.6	7.891e+00	5.026e+00	2.029	.632
2.0	1109	175.6	5.509e+00	3.217e+00	1.098	.383
2.5	1386	234.6	4.124e+00	2.219e+00	.659	.265
3.0	1663	299.0	3.235e+00	1.611e+00	.424	.202
3.5	1940	368.4	2.626e+00	1.213e+00	.287	.165
4.0	2218	442.5	2.186e+00	9.378e-01	.201	.143
4.5	2495	521.0	1.857e+00	7.427e-01	.146	.128
5.0	2772	603.7	1.602e+00	5.977e-01	.108	.118
5.5	3049	690.3	1.401e+00	4.877e-01	.082	.111
6.0	3326	780.7	1.239e+00	4.039e-01	.063	.106

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
CORAL ZONE INSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 16 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	7.920e-01	1.263e+00
1.0	7.010e-01	1.427e+00
1.5	6.370e-01	1.570e+00
2.0	5.840e-01	1.712e+00
2.5	5.380e-01	1.859e+00
3.0	4.980e-01	2.008e+00
3.5	4.620e-01	2.165e+00
4.0	4.290e-01	2.331e+00
4.5	4.000e-01	2.500e+00
5.0	3.730e-01	2.681e+00
5.5	3.480e-01	2.874e+00
6.0	3.260e-01	3.067e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
CORAL ZONE INSHORE

Init'al Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 16.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.075 m/s (10.4 %)
Current Direction : WNW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	4.565
.5	135	38.1	2.538e+01	2.010e+01	11.462	1.300
1.0	270	76.4	1.267e+01	8.879e+00	4.405	.567
1.5	405	122.6	7.891e+00	5.026e+00	2.029	.319
2.0	540	175.6	5.509e+00	3.217e+00	1.098	.223
2.5	675	234.6	4.124e+00	2.219e+00	.659	.177
3.0	810	299.0	3.235e+00	1.611e+00	.424	.153
3.5	945	368.4	2.626e+00	1.213e+00	.287	.138
4.0	1080	442.5	2.186e+00	9.378e-01	.201	.129
4.5	1215	521.0	1.857e+00	7.427e-01	.146	.124
5.0	1350	603.7	1.602e+00	5.977e-01	.108	.120
5.5	1485	690.3	1.401e+00	4.877e-01	.082	.117
6.0	1620	780.7	1.239e+00	4.039e-01	.063	.115

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
CORAL ZONE INSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 16 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	7.920e-01	1.263e+00
1.0	7.010e-01	1.427e+00
1.5	6.370e-01	1.570e+00
2.0	5.840e-01	1.712e+00
2.5	5.380e-01	1.859e+00
3.0	4.980e-01	2.008e+00
3.5	4.620e-01	2.165e+00
4.0	4.290e-01	2.331e+00
4.5	4.000e-01	2.500e+00
5.0	3.730e-01	2.681e+00
5.5	3.480e-01	2.874e+00
6.0	3.260e-01	3.067e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
CORAL ZONE INSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 16.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.037 m/s (4.1 %)
Current Direction : NW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width-(m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	1.873
.5	67	38.1	2.538e+01	2.010e+01	11.462	.586
1.0	133	76.4	1.267e+01	8.879e+00	4.405	.297
1.5	200	122.6	7.891e+00	5.026e+00	2.029	.199
2.0	266	175.6	5.509e+00	3.217e+00	1.098	.161
2.5	333	234.6	4.124e+00	2.219e+00	.659	.143
3.0	400	299.0	3.235e+00	1.611e+00	.424	.133
3.5	466	368.4	2.626e+00	1.213e+00	.287	.128
4.0	533	442.5	2.186e+00	9.378e-01	.201	.124
4.5	599	521.0	1.857e+00	7.427e-01	.146	.122
5.0	666	603.7	1.602e+00	5.977e-01	.108	.120
5.5	733	690.3	1.401e+00	4.877e-01	.082	.119
6.0	799	780.7	1.239e+00	4.039e-01	.063	.119

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
CORAL ZONE INSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 16 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	7.920e-01	1.263e+00
1.0	7.010e-01	1.427e+00
1.5	6.370e-01	1.570e+00
2.0	5.840e-01	1.712e+00
2.5	5.380e-01	1.859e+00
3.0	4.980e-01	2.008e+00
3.5	4.620e-01	2.165e+00
4.0	4.290e-01	2.331e+00
4.5	4.000e-01	2.500e+00
5.0	3.730e-01	2.681e+00
5.5	3.480e-01	2.874e+00
6.0	3.260e-01	3.067e+00

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
CORAL ZONE INSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 16.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.026 m/s (2.9 %)
Current Direction : NNW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width-(m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	1.360
.5	47	38.1	2.538e+01	2.010e+01	11.462	.450
1.0	94	76.4	1.267e+01	8.879e+00	4.405	.245
1.5	140	122.6	7.891e+00	5.026e+00	2.029	.176
2.0	187	175.6	5.509e+00	3.217e+00	1.098	.149
2.5	234	234.6	4.124e+00	2.219e+00	.659	.137
3.0	281	299.0	3.235e+00	1.611e+00	.424	.130
3.5	328	368.4	2.626e+00	1.213e+00	.287	.126
4.0	374	442.5	2.186e+00	9.378e-01	.201	.123
4.5	421	521.0	1.857e+00	7.427e-01	.146	.122
5.0	468	603.7	1.602e+00	5.977e-01	.108	.121
5.5	515	690.3	1.401e+00	4.877e-01	.082	.120
6.0	562	780.7	1.239e+00	4.039e-01	.063	.119

APPENDIX A-4

Sandy Zone

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
SANDY ZONE OFFSHORE, PLUME DEPTH=20m

Time (hours)	Relative Concentration Decrease Per Grain Size Fraction (mm) (weight percent list below grain size)								
	4.000	2.000	1.000	.500	.250	.125	.063	.020	all (mm)
	.010	.019	.049	.100	.195	.500	.109	.018	(wt %)
.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
.5	.000	.000	.000	.001	.045	.236	.684	.962	.219
1.0	.000	.000	.000	.000	.002	.056	.468	.926	.096
1.5	.000	.000	.000	.000	.000	.013	.320	.891	.058
2.0	.000	.000	.000	.000	.000	.003	.219	.858	.041
2.5	.000	.000	.000	.000	.000	.001	.149	.826	.032
3.0	.000	.000	.000	.000	.000	.000	.102	.795	.026
3.5	.000	.000	.000	.000	.000	.000	.070	.765	.021
4.0	.000	.000	.000	.000	.000	.000	.048	.736	.018
4.5	.000	.000	.000	.000	.000	.000	.033	.708	.016
5.0	.000	.000	.000	.000	.000	.000	.022	.682	.015
5.5	.000	.000	.000	.000	.000	.000	.015	.656	.013
6.0	.000	.000	.000	.000	.000	.000	.010	.631	.013
6.5	.000	.000	.000	.000	.000	.000	.007	.608	.012
7.0	.000	.000	.000	.000	.000	.000	.005	.585	.011
7.5	.000	.000	.000	.000	.000	.000	.003	.563	.010
8.0	.000	.000	.000	.000	.000	.000	.002	.542	.010

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
SANDY ZONE OFFSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 20 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.200e-01	4.545e+00
1.0	9.600e-02	1.042e+01
1.5	5.800e-02	1.724e+01
2.0	4.100e-02	2.439e+01
2.5	3.200e-02	3.125e+01
3.0	2.600e-02	3.846e+01
3.5	2.100e-02	4.762e+01
4.0	1.800e-02	5.556e+01
4.5	1.600e-02	6.250e+01
5.0	1.500e-02	6.667e+01
5.5	1.300e-02	7.692e+01
6.0	1.300e-02	7.692e+01

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
SANDY ZONE OFFSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 20.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.000 m/s (7.5 %)
Current Direction : CALM
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	3.326
.5	0	38.1	2.538e+01	5.583e+00	2.345	.288
1.0	0	76.4	1.267e+01	1.216e+00	.288	.134
1.5	1	122.6	7.891e+00	4.576e-01	.075	.118
2.0	1	175.6	5.509e+00	2.259e-01	.028	.114
2.5	1	234.6	4.124e+00	1.320e-01	.014	.113
3.0	1	299.0	3.235e+00	8.412e-02	.007	.112
3.5	1	368.4	2.626e+00	5.514e-02	.004	.112
4.0	1	442.5	2.186e+00	3.935e-02	.003	.112
4.5	2	521.0	1.857e+00	2.971e-02	.002	.112
5.0	2	603.7	1.602e+00	2.404e-02	.001	.112
5.5	2	690.3	1.401e+00	1.822e-02	.001	.112
6.0	2	780.7	1.239e+00	1.611e-02	.001	.112

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
SANDY ZONE OFFSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 20 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.200e-01	4.545e+00
1.0	9.600e-02	1.042e+01
1.5	5.800e-02	1.724e+01
2.0	4.100e-02	2.439e+01
2.5	3.200e-02	3.125e+01
3.0	2.600e-02	3.846e+01
3.5	2.100e-02	4.762e+01
4.0	1.800e-02	5.556e+01
4.5	1.600e-02	6.250e+01
5.0	1.500e-02	6.667e+01
5.5	1.300e-02	7.692e+01
6.0	1.300e-02	7.692e+01

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
SANDY ZONE OFFSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 20.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.037 m/s (2.9 %)
Current Direction : N
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	1.360
.5	67	38.1	2.538e+01	5.583e+00	2.345	.185
1.0	133	76.4	1.267e+01	1.216e+00	.288	.126
1.5	200	122.6	7.891e+00	4.576e-01	.075	.120
2.0	266	175.6	5.509e+00	2.259e-01	.028	.118
2.5	333	234.6	4.124e+00	1.320e-01	.014	.118
3.0	400	299.0	3.235e+00	8.412e-02	.007	.118
3.5	466	368.4	2.626e+00	5.514e-02	.004	.118
4.0	533	442.5	2.186e+00	3.935e-02	.003	.118
4.5	599	521.0	1.857e+00	2.971e-02	.002	.118
5.0	666	603.7	1.602e+00	2.404e-02	.001	.118
5.5	733	690.3	1.401e+00	1.822e-02	.001	.118
6.0	799	780.7	1.239e+00	1.611e-02	.001	.118

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
SANDY ZONE OFFSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 20 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.200e-01	4.545e+00
1.0	9.600e-02	1.042e+01
1.5	5.800e-02	1.724e+01
2.0	4.100e-02	2.439e+01
2.5	3.200e-02	3.125e+01
3.0	2.600e-02	3.846e+01
3.5	2.100e-02	4.762e+01
4.0	1.800e-02	5.556e+01
4.5	1.600e-02	6.250e+01
5.0	1.500e-02	6.667e+01
5.5	1.300e-02	7.692e+01
6.0	1.300e-02	7.692e+01

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
SANDY ZONE OFFSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 20.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.039 m/s (2.7 %)
Current Direction : NNE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	1.275
.5	70	38.1	2.538e+01	5.583e+00	2.345	.181
1.0	140	76.4	1.267e+01	1.216e+00	.288	.126
1.5	211	122.6	7.891e+00	4.576e-01	.075	.120
2.0	281	175.6	5.509e+00	2.259e-01	.028	.118
2.5	351	234.6	4.124e+00	1.320e-01	.014	.118
3.0	421	299.0	3.235e+00	8.412e-02	.007	.118
3.5	491	368.4	2.626e+00	5.514e-02	.004	.118
4.0	562	442.5	2.186e+00	3.935e-02	.003	.118
4.5	632	521.0	1.857e+00	2.971e-02	.002	.118
5.0	702	603.7	1.602e+00	2.404e-02	.001	.118
5.5	772	690.3	1.401e+00	1.822e-02	.001	.118
6.0	842	780.7	1.239e+00	1.611e-02	.001	.118

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
SANDY ZONE OFFSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 20 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.200e-01	4.545e+00
1.0	9.600e-02	1.042e+01
1.5	5.800e-02	1.724e+01
2.0	4.100e-02	2.439e+01
2.5	3.200e-02	3.125e+01
3.0	2.600e-02	3.846e+01
3.5	2.100e-02	4.762e+01
4.0	1.800e-02	5.556e+01
4.5	1.600e-02	6.250e+01
5.0	1.500e-02	6.667e+01
5.5	1.300e-02	7.692e+01
6.0	1.300e-02	7.692e+01

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
SANDY ZONE OFFSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 20.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.046 m/s (4 %)
Current Direction : NE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	1.830
.5	83	38.1	2.538e+01	5.583e+00	2.345	.210
1.0	166	76.4	1.267e+01	1.216e+00	.288	.128
1.5	248	122.6	7.891e+00	4.576e-01	.075	.119
2.0	331	175.6	5.509e+00	2.259e-01	.028	.117
2.5	414	234.6	4.124e+00	1.320e-01	.014	.117
3.0	497	299.0	3.235e+00	8.412e-02	.007	.116
3.5	580	368.4	2.626e+00	5.514e-02	.004	.116
4.0	662	442.5	2.186e+00	3.935e-02	.003	.116
4.5	745	521.0	1.857e+00	2.971e-02	.002	.116
5.0	828	603.7	1.602e+00	2.404e-02	.001	.116
5.5	911	690.3	1.401e+00	1.822e-02	.001	.116
6.0	994	780.7	1.239e+00	1.611e-02	.001	.116

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
SANDY ZONE OFFSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 20 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.200e-01	4.545e+00
1.0	9.600e-02	1.042e+01
1.5	5.800e-02	1.724e+01
2.0	4.100e-02	2.439e+01
2.5	3.200e-02	3.125e+01
3.0	2.600e-02	3.846e+01
3.5	2.100e-02	4.762e+01
4.0	1.800e-02	5.556e+01
4.5	1.600e-02	6.250e+01
5.0	1.500e-02	6.667e+01
5.5	1.300e-02	7.692e+01
6.0	1.300e-02	7.692e+01

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
SANDY ZONE OFFSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 20.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.058 m/s (6.3 %)
Current Direction : ENE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	2.813
.5	104	38.1	2.538e+01	5.583e+00	2.345	.261
1.0	209	76.4	1.267e+01	1.216e+00	.288	.132
1.5	313	122.6	7.891e+00	4.576e-01	.075	.118
2.0	418	175.6	5.509e+00	2.259e-01	.028	.115
2.5	522	234.6	4.124e+00	1.320e-01	.014	.114
3.0	626	299.0	3.235e+00	8.412e-02	.007	.114
3.5	731	368.4	2.626e+00	5.514e-02	.004	.114
4.0	835	442.5	2.186e+00	3.935e-02	.003	.114
4.5	940	521.0	1.857e+00	2.971e-02	.002	.113
5.0	1044	603.7	1.602e+00	2.404e-02	.001	.113
5.5	1148	690.3	1.401e+00	1.822e-02	.001	.113
6.0	1253	780.7	1.239e+00	1.611e-02	.001	.113

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
SANDY ZONE OFFSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 20 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.200e-01	4.545e+00
1.0	9.600e-02	1.042e+01
1.5	5.800e-02	1.724e+01
2.0	4.100e-02	2.439e+01
2.5	3.200e-02	3.125e+01
3.0	2.600e-02	3.846e+01
3.5	2.100e-02	4.762e+01
4.0	1.800e-02	5.556e+01
4.5	1.600e-02	6.250e+01
5.0	1.500e-02	6.667e+01
5.5	1.300e-02	7.692e+01
6.0	1.300e-02	7.692e+01

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
SANDY ZONE OFFSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 20.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.079 m/s (12.3 %)
Current Direction : E
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	5.377
.5	142	38.1	2.538e+01	5.583e+00	2.345	.395
1.0	284	76.4	1.267e+01	1.216e+00	.288	.142
1.5	427	122.6	7.891e+00	4.576e-01	.075	.115
2.0	569	175.6	5.509e+00	2.259e-01	.028	.110
2.5	711	234.6	4.124e+00	1.320e-01	.014	.108
3.0	853	299.0	3.235e+00	8.412e-02	.007	.107
3.5	995	368.4	2.626e+00	5.514e-02	.004	.107
4.0	1138	442.5	2.186e+00	3.935e-02	.003	.106
4.5	1280	521.0	1.857e+00	2.971e-02	.002	.106
5.0	1422	603.7	1.602e+00	2.404e-02	.001	.106
5.5	1564	690.3	1.401e+00	1.822e-02	.001	.106
6.0	1706	780.7	1.239e+00	1.611e-02	.001	.106

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
SANDY ZONE OFFSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 20 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.200e-01	4.545e+00
1.0	9.600e-02	1.042e+01
1.5	5.800e-02	1.724e+01
2.0	4.100e-02	2.439e+01
2.5	3.200e-02	3.125e+01
3.0	2.600e-02	3.846e+01
3.5	2.100e-02	4.762e+01
4.0	1.800e-02	5.556e+01
4.5	1.600e-02	6.250e+01
5.0	1.500e-02	6.667e+01
5.5	1.300e-02	7.692e+01
6.0	1.300e-02	7.692e+01

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
SANDY ZONE OFFSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 20.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.078 m/s (10.5 %)
Current Direction : ESE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	4.608
.5	140	38.1	2.538e+01	5.583e+00	2.345	.355
1.0	281	76.4	1.267e+01	1.216e+00	.288	.139
1.5	421	122.6	7.891e+00	4.576e-01	.075	.116
2.0	562	175.6	5.509e+00	2.259e-01	.028	.111
2.5	702	234.6	4.124e+00	1.320e-01	.014	.110
3.0	842	299.0	3.235e+00	8.412e-02	.007	.109
3.5	983	368.4	2.626e+00	5.514e-02	.004	.109
4.0	1123	442.5	2.186e+00	3.935e-02	.003	.109
4.5	1264	521.0	1.857e+00	2.971e-02	.002	.108
5.0	1404	603.7	1.602e+00	2.404e-02	.001	.108
5.5	1544	690.3	1.401e+00	1.822e-02	.001	.108
6.0	1685	780.7	1.239e+00	1.611e-02	.001	.108

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
SANDY ZONE OFFSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 20 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.200e-01	4.545e+00
1.0	9.600e-02	1.042e+01
1.5	5.800e-02	1.724e+01
2.0	4.100e-02	2.439e+01
2.5	3.200e-02	3.125e+01
3.0	2.600e-02	3.846e+01
3.5	2.100e-02	4.762e+01
4.0	1.800e-02	5.556e+01
4.5	1.600e-02	6.250e+01
5.0	1.500e-02	6.667e+01
5.5	1.300e-02	7.692e+01
6.0	1.300e-02	7.692e+01

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
SANDY ZONE OFFSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 20.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.057 m/s (5.6 %)
Current Direction : SE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	2.514
.5	103	38.1	2.538e+01	5.583e+00	2.345	.246
1.0	205	76.4	1.267e+01	1.216e+00	.288	.130
1.5	308	122.6	7.891e+00	4.576e-01	.075	.118
2.0	410	175.6	5.509e+00	2.259e-01	.028	.116
2.5	513	234.6	4.124e+00	1.320e-01	.014	.115
3.0	616	299.0	3.235e+00	8.412e-02	.007	.115
3.5	718	368.4	2.626e+00	5.514e-02	.004	.114
4.0	821	442.5	2.186e+00	3.935e-02	.003	.114
4.5	923	521.0	1.857e+00	2.971e-02	.002	.114
5.0	1026	603.7	1.602e+00	2.404e-02	.001	.114
5.5	1129	690.3	1.401e+00	1.822e-02	.001	.114
6.0	1231	780.7	1.239e+00	1.611e-02	.001	.114

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
SANDY ZONE OFFSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 20 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.200e-01	4.545e+00
1.0	9.600e-02	1.042e+01
1.5	5.800e-02	1.724e+01
2.0	4.100e-02	2.439e+01
2.5	3.200e-02	3.125e+01
3.0	2.600e-02	3.846e+01
3.5	2.100e-02	4.762e+01
4.0	1.800e-02	5.556e+01
4.5	1.600e-02	6.250e+01
5.0	1.500e-02	6.667e+01
5.5	1.300e-02	7.692e+01
6.0	1.300e-02	7.692e+01

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
SANDY ZONE OFFSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 20.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.042 m/s (2.8 %)
Current Direction : SSE
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width. (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	1.317
.5	76	38.1	2.538e+01	5.583e+00	2.345	.183
1.0	151	76.4	1.267e+01	1.216e+00	.288	.126
1.5	227	122.6	7.891e+00	4.576e-01	.075	.120
2.0	302	175.6	5.509e+00	2.259e-01	.028	.118
2.5	378	234.6	4.124e+00	1.320e-01	.014	.118
3.0	454	299.0	3.235e+00	8.412e-02	.007	.118
3.5	529	368.4	2.626e+00	5.514e-02	.004	.118
4.0	605	442.5	2.186e+00	3.935e-02	.003	.118
4.5	680	521.0	1.857e+00	2.971e-02	.002	.118
5.0	756	603.7	1.602e+00	2.404e-02	.001	.118
5.5	832	690.3	1.401e+00	1.822e-02	.001	.118
6.0	907	780.7	1.239e+00	1.611e-02	.001	.118

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
SANDY ZONE OFFSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 20 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.200e-01	4.545e+00
1.0	9.600e-02	1.042e+01
1.5	5.800e-02	1.724e+01
2.0	4.100e-02	2.439e+01
2.5	3.200e-02	3.125e+01
3.0	2.600e-02	3.846e+01
3.5	2.100e-02	4.762e+01
4.0	1.800e-02	5.556e+01
4.5	1.600e-02	6.250e+01
5.0	1.500e-02	6.667e+01
5.5	1.300e-02	7.692e+01
6.0	1.300e-02	7.692e+01

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
SANDY ZONE OFFSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 20.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.035 m/s (1.8 %)
Current Direction : S
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	.890
.5	63	38.1	2.538e+01	5.583e+00	2.345	.161
1.0	126	76.4	1.267e+01	1.216e+00	.288	.124
1.5	189	122.6	7.891e+00	4.576e-01	.075	.120
2.0	252	175.6	5.509e+00	2.259e-01	.028	.119
2.5	315	234.6	4.124e+00	1.320e-01	.014	.119
3.0	378	299.0	3.235e+00	8.412e-02	.007	.119
3.5	441	368.4	2.626e+00	5.514e-02	.004	.119
4.0	504	442.5	2.186e+00	3.935e-02	.003	.119
4.5	567	521.0	1.857e+00	2.971e-02	.002	.119
5.0	630	603.7	1.602e+00	2.404e-02	.001	.119
5.5	693	690.3	1.401e+00	1.822e-02	.001	.119
6.0	756	780.7	1.239e+00	1.611e-02	.001	.119

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
SANDY ZONE OFFSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 20 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.200e-01	4.545e+00
1.0	9.600e-02	1.042e+01
1.5	5.800e-02	1.724e+01
2.0	4.100e-02	2.439e+01
2.5	3.200e-02	3.125e+01
3.0	2.600e-02	3.846e+01
3.5	2.100e-02	4.762e+01
4.0	1.800e-02	5.556e+01
4.5	1.600e-02	6.250e+01
5.0	1.500e-02	6.667e+01
5.5	1.300e-02	7.692e+01
6.0	1.300e-02	7.692e+01

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
SANDY ZONE OFFSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 20.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.034 m/s (1.8 %)
Current Direction : SSW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	.890
.5	61	38.1	2.538e+01	5.583e+00	2.345	.161
1.0	122	76.4	1.267e+01	1.216e+00	.288	.124
1.5	184	122.6	7.891e+00	4.576e-01	.075	.120
2.0	245	175.6	5.509e+00	2.259e-01	.028	.119
2.5	306	234.6	4.124e+00	1.320e-01	.014	.119
3.0	367	299.0	3.235e+00	8.412e-02	.007	.119
3.5	428	368.4	2.626e+00	5.514e-02	.004	.119
4.0	490	442.5	2.186e+00	3.935e-02	.003	.119
4.5	551	521.0	1.857e+00	2.971e-02	.002	.119
5.0	612	603.7	1.602e+00	2.404e-02	.001	.119
5.5	673	690.3	1.401e+00	1.822e-02	.001	.119
6.0	734	780.7	1.239e+00	1.611e-02	.001	.119

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
SANDY ZONE OFFSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 20 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.200e-01	4.545e+00
1.0	9.600e-02	1.042e+01
1.5	5.800e-02	1.724e+01
2.0	4.100e-02	2.439e+01
2.5	3.200e-02	3.125e+01
3.0	2.600e-02	3.846e+01
3.5	2.100e-02	4.762e+01
4.0	1.800e-02	5.556e+01
4.5	1.600e-02	6.250e+01
5.0	1.500e-02	6.667e+01
5.5	1.300e-02	7.692e+01
6.0	1.300e-02	7.692e+01

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
SANDY ZONE OFFSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 20.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.046 m/s (3.1 %)
Current Direction : SW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	1.446
.5	83	38.1	2.538e+01	5.583e+00	2.345	.190
1.0	166	76.4	1.267e+01	1.216e+00	.288	.126
1.5	248	122.6	7.891e+00	4.576e-01	.075	.120
2.0	331	175.6	5.509e+00	2.259e-01	.028	.118
2.5	414	234.6	4.124e+00	1.320e-01	.014	.118
3.0	497	299.0	3.235e+00	8.412e-02	.007	.117
3.5	580	368.4	2.626e+00	5.514e-02	.004	.117
4.0	662	442.5	2.186e+00	3.935e-02	.003	.117
4.5	745	521.0	1.857e+00	2.971e-02	.002	.117
5.0	828	603.7	1.602e+00	2.404e-02	.001	.117
5.5	911	690.3	1.401e+00	1.822e-02	.001	.117
6.0	994	780.7	1.239e+00	1.611e-02	.001	.117

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
SANDY ZONE OFFSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 20 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.200e-01	4.545e+00
1.0	9.600e-02	1.042e+01
1.5	5.800e-02	1.724e+01
2.0	4.100e-02	2.439e+01
2.5	3.200e-02	3.125e+01
3.0	2.600e-02	3.846e+01
3.5	2.100e-02	4.762e+01
4.0	1.800e-02	5.556e+01
4.5	1.600e-02	6.250e+01
5.0	1.500e-02	6.667e+01
5.5	1.300e-02	7.692e+01
6.0	1.300e-02	7.692e+01

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
SANDY ZONE OFFSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 20.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.074 m/s (6 %)
Current Direction : WSW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	2.685
.5	133	38.1	2.538e+01	5.583e+00	2.345	.254
1.0	266	76.4	1.267e+01	1.216e+00	.288	.131
1.5	400	122.6	7.891e+00	4.576e-01	.075	.118
2.0	533	175.6	5.509e+00	2.259e-01	.028	.115
2.5	666	234.6	4.124e+00	1.320e-01	.014	.115
3.0	799	299.0	3.235e+00	8.412e-02	.007	.114
3.5	932	368.4	2.626e+00	5.514e-02	.004	.114
4.0	1066	442.5	2.186e+00	3.935e-02	.003	.114
4.5	1199	521.0	1.857e+00	2.971e-02	.002	.114
5.0	1332	603.7	1.602e+00	2.404e-02	.001	.114
5.5	1465	690.3	1.401e+00	1.822e-02	.001	.114
6.0	1598	780.7	1.239e+00	1.611e-02	.001	.114

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
SANDY ZONE OFFSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 20 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.200e-01	4.545e+00
1.0	9.600e-02	1.042e+01
1.5	5.800e-02	1.724e+01
2.0	4.100e-02	2.439e+01
2.5	3.200e-02	3.125e+01
3.0	2.600e-02	3.846e+01
3.5	2.100e-02	4.762e+01
4.0	1.800e-02	5.556e+01
4.5	1.600e-02	6.250e+01
5.0	1.500e-02	6.667e+01
5.5	1.300e-02	7.692e+01
6.0	1.300e-02	7.692e+01

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
SANDY ZONE OFFSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 20.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.107 m/s (13.9 %)
Current Direction : W
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	6.060
.5	193	38.1	2.538e+01	5.583e+00	2.345	.430
1.0	385	76.4	1.267e+01	1.216e+00	.288	.144
1.5	578	122.6	7.891e+00	4.576e-01	.075	.115
2.0	770	175.6	5.509e+00	2.259e-01	.028	.108
2.5	963	234.6	4.124e+00	1.320e-01	.014	.106
3.0	1156	299.0	3.235e+00	8.412e-02	.007	.105
3.5	1348	368.4	2.626e+00	5.514e-02	.004	.105
4.0	1541	442.5	2.186e+00	3.935e-02	.003	.105
4.5	1733	521.0	1.857e+00	2.971e-02	.002	.104
5.0	1926	603.7	1.602e+00	2.404e-02	.001	.104
5.5	2119	690.3	1.401e+00	1.822e-02	.001	.104
6.0	2311	780.7	1.239e+00	1.611e-02	.001	.104

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
SANDY ZONE OFFSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 20 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.200e-01	4.545e+00
1.0	9.600e-02	1.042e+01
1.5	5.800e-02	1.724e+01
2.0	4.100e-02	2.439e+01
2.5	3.200e-02	3.125e+01
3.0	2.600e-02	3.846e+01
3.5	2.100e-02	4.762e+01
4.0	1.800e-02	5.556e+01
4.5	1.600e-02	6.250e+01
5.0	1.500e-02	6.667e+01
5.5	1.300e-02	7.692e+01
6.0	1.300e-02	7.692e+01

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
SANDY ZONE OFFSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 20.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.084 m/s (10.2 %)
Current Direction : WNW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	4.479
.5	151	38.1	2.538e+01	5.583e+00	2.345	.348
1.0	302	76.4	1.267e+01	1.216e+00	.288	.138
1.5	454	122.6	7.891e+00	4.576e-01	.075	.116
2.0	605	175.6	5.509e+00	2.259e-01	.028	.112
2.5	756	234.6	4.124e+00	1.320e-01	.014	.110
3.0	907	299.0	3.235e+00	8.412e-02	.007	.109
3.5	1058	368.4	2.626e+00	5.514e-02	.004	.109
4.0	1210	442.5	2.186e+00	3.935e-02	.003	.109
4.5	1361	521.0	1.857e+00	2.971e-02	.002	.109
5.0	1512	603.7	1.602e+00	2.404e-02	.001	.109
5.5	1663	690.3	1.401e+00	1.822e-02	.001	.109
6.0	1814	780.7	1.239e+00	1.611e-02	.001	.109

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
SANDY ZONE OFFSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 20 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.200e-01	4.545e+00
1.0	9.600e-02	1.042e+01
1.5	5.800e-02	1.724e+01
2.0	4.100e-02	2.439e+01
2.5	3.200e-02	3.125e+01
3.0	2.600e-02	3.846e+01
3.5	2.100e-02	4.762e+01
4.0	1.800e-02	5.556e+01
4.5	1.600e-02	6.250e+01
5.0	1.500e-02	6.667e+01
5.5	1.300e-02	7.692e+01
6.0	1.300e-02	7.692e+01

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
SANDY ZONE OFFSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 20.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.056 m/s (5.3 %)
Current Direction : NW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	2.386
.5	101	38.1	2.538e+01	5.583e+00	2.345	.239
1.0	202	76.4	1.267e+01	1.216e+00	.288	.130
1.5	302	122.6	7.891e+00	4.576e-01	.075	.119
2.0	403	175.6	5.509e+00	2.259e-01	.028	.116
2.5	504	234.6	4.124e+00	1.320e-01	.014	.115
3.0	605	299.0	3.235e+00	8.412e-02	.007	.115
3.5	706	368.4	2.626e+00	5.514e-02	.004	.115
4.0	806	442.5	2.186e+00	3.935e-02	.003	.115
4.5	907	521.0	1.857e+00	2.971e-02	.002	.115
5.0	1008	603.7	1.602e+00	2.404e-02	.001	.115
5.5	1109	690.3	1.401e+00	1.822e-02	.001	.115
6.0	1210	780.7	1.239e+00	1.611e-02	.001	.115

RELATIVE CONCENTRATION AND DILUTION
DUE ONLY TO THE FALLOUT OF SUSPENDED SEDIMENTS
SANDY ZONE OFFSHORE

Initial Plume Width (B) : 10 m
Depth of the Plume (H) : 20 m

Time (hours)	Relative Concentration (Cx/Ci)	Dilution
.0	1.000e+00	1.000e+00
.5	2.200e-01	4.545e+00
1.0	9.600e-02	1.042e+01
1.5	5.800e-02	1.724e+01
2.0	4.100e-02	2.439e+01
2.5	3.200e-02	3.125e+01
3.0	2.600e-02	3.846e+01
3.5	2.100e-02	4.762e+01
4.0	1.800e-02	5.556e+01
4.5	1.600e-02	6.250e+01
5.0	1.500e-02	6.667e+01
5.5	1.300e-02	7.692e+01
6.0	1.300e-02	7.692e+01

TURBIDITY CONCENTRATION FOR A CONTINUOUS DREDGING OPERATION
SANDY ZONE OFFSHORE

Initial Sediment Concentration (Ci): 70.000 mg/l
Depth of Water Column (h) : 20.00 m
Initial Plume Width (B) : 10 m
Current Speed (U) and Frequency : 0.044 m/s (3.2 %)
Current Direction : NNW
Constant (a) : 1.67 (m^2/3)/hr
Nth Law of K (n) : 1.333
Initial Diffusion Coeff. (Ko) : 35.9763 (m^2)/hr

Time (hours)	Dist. (m)	Plume Width (m)	Peak Concentrations (mg/l) Nonsettling	Settling	Turbidity (ntu)	Mean Turb. (ntu)
.0	0	10.0	7.000e+01	7.000e+01	42.850	1.488
.5	79	38.1	2.538e+01	5.583e+00	2.345	.192
1.0	158	76.4	1.267e+01	1.216e+00	.288	.126
1.5	238	122.6	7.891e+00	4.576e-01	.075	.120
2.0	317	175.6	5.509e+00	2.259e-01	.028	.118
2.5	396	234.6	4.124e+00	1.320e-01	.014	.118
3.0	475	299.0	3.235e+00	8.412e-02	.007	.117
3.5	554	368.4	2.626e+00	5.514e-02	.004	.117
4.0	634	442.5	2.186e+00	3.935e-02	.003	.117
4.5	713	521.0	1.857e+00	2.971e-02	.002	.117
5.0	792	603.7	1.602e+00	2.404e-02	.001	.117
5.5	871	690.3	1.401e+00	1.822e-02	.001	.117
6.0	950	780.7	1.239e+00	1.611e-02	.001	.117

Appendix XI

Time-Integrated Plume Modeling for the Wastewater Treatment Plant at Fort Kamehameha

TIME-INTEGRATED PLUME MODELING FOR THE WASTEWATER TREATMENT PLANT AT FORT KAMEHAMEHA

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January 1997

#95-34

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1.0 INTRODUCTION

The Wastewater Treatment Plant (WWTP) at Fort Kamehameha is located near the entrance to Pearl Harbor on the south shore of O'ahu (Figure 1), and presently discharges into the entrance channel waters, which are classified as Class 2 Inland Estuary under State of Hawai'i, Department of Health (DOH) regulations. A proposed 3,000 meter long extension would result in discharge into Class A Open Coastal waters. Two diffuser alternatives are under consideration, one in 21 meters water depth, and one in 46 meters depth (Figure 2). This study is a mathematical model intended to show the behavior of the wastewater fields generated by the diffuser alternatives over the course of one year. The model uses actual flow rates from the plant and physical oceanographic measurements to simulate the behavior of the wastewater plume, and gives the designers a quantified description of wastewater impacts along the shoreline and within Māmala Bay.

An oceanographic study completed for the project (SSFM Engineers, Inc., 1996) provides a year of nearly continuous physical oceanographic data as input. An Aanderaa DCM12 acoustic doppler current profiler (ADCP) was deployed at a depth of 39 meters and measured the average current speed and direction in five discrete 12 meter layers through the water column. Seawater density was calculated from thermistor data recorded at three depths in the water column.

Two similar studies have previously been done for Māmala Bay to evaluate the impacts of the Sand Island and Barbers Point municipal outfalls. Noda (1993) modeled the effects of the Barbers Point outfall, while the Māmala Bay Study (1996) included modeling of both the Sand Island and Barbers Point outfalls (Roberts, 1996, MB-4). The present study closely follows the methodology of Roberts (ibid) in order to allow direct comparison and to address the cumulative impacts on the bay by summing the impacts of all three outfalls.

2.0 METHODS

2.1 Outfall Configurations

Two outfall configurations were selected for modeling based upon the project oceanographic study and initial wastewater plume modeling (SSFM Engineers, Inc., 1996). Prior to the oceanographic study, the Navy had planned to locate the diffuser at approximately the 37

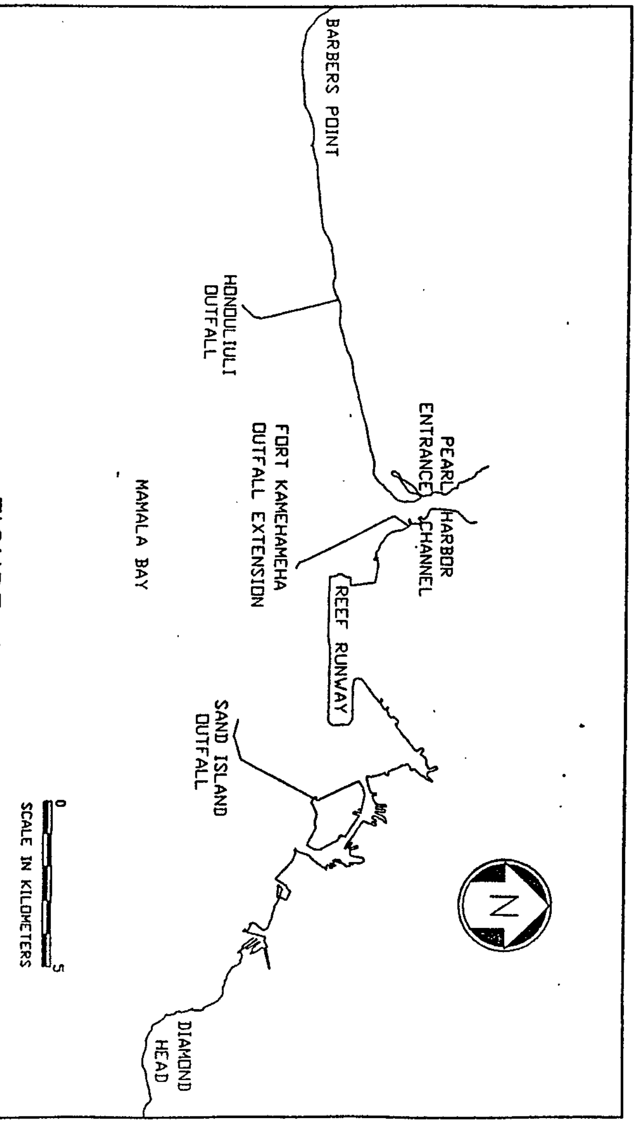
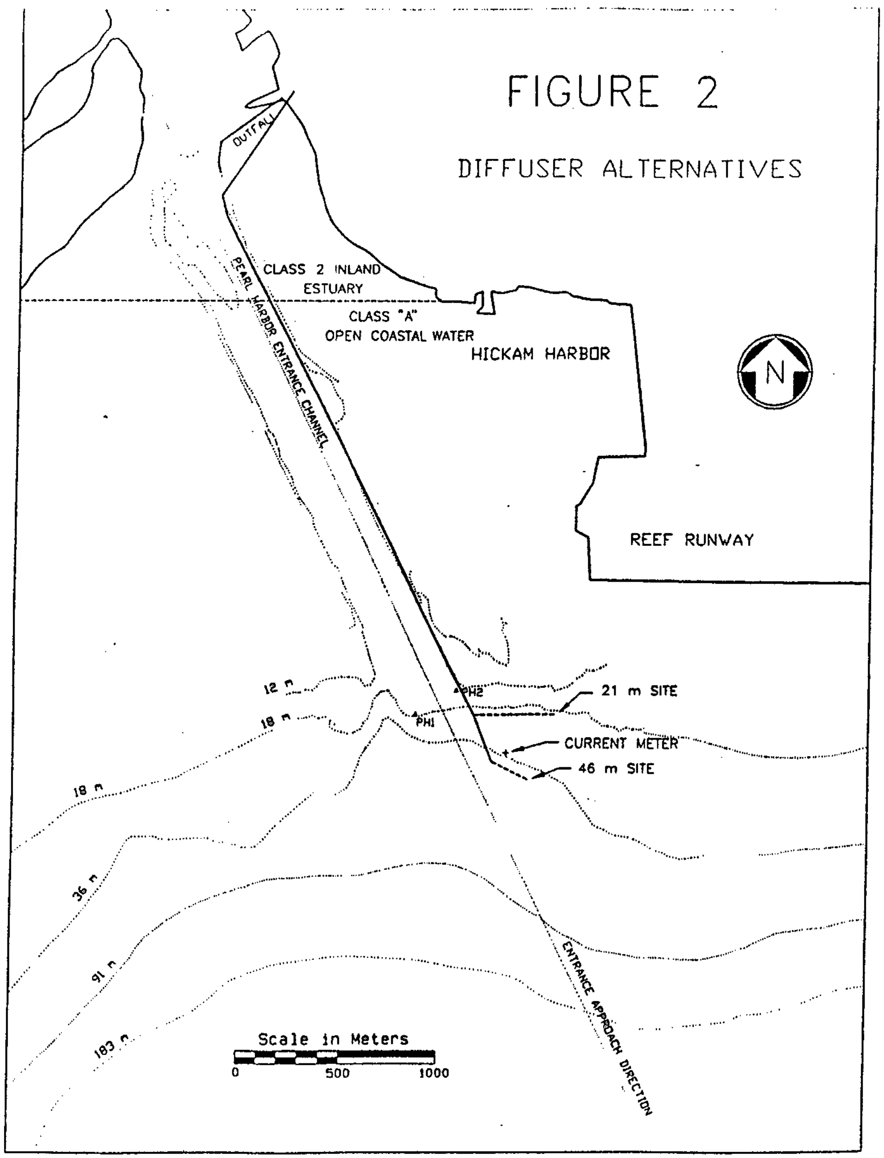


FIGURE 1

GENERAL PROJECT LOCATION
SOUTH SHORE OF OAHU

FIGURE 2

DIFFUSER ALTERNATIVES



meter depth. However, geophysical surveys and diving reconnaissance revealed an extensive sand deposit extending throughout the project area. In some locations the sand exceeds 10 meters in thickness, and the 37 meter diffuser location is on a relatively steep 1 on 6 slope. Re-routing the outfall to avoid the sand deposit is not feasible due to the required distance, so two alternative diffuser locations are being investigated at the 21 meter depth and 46 meter depth. The 21 meter depth location is just inshore of the sand deposit, where the diffuser could be placed in a trench excavated in the hard bottom and protected with either tremie concrete or armor stone. Extending the outfall out to the 46 meter depth is the other option. At this depth the bottom is still sand, but at a more shallow 1 on 14 slope and apparently more stable.

Plume modeling for the oceanographic study established recommended diffuser lengths of 400 meters for the 21 meter depth location, and 200 meters for the 46 meter depth location. These recommendations were confirmed with PACDIV prior to this modeling effort.

2.2 Mathematical Model

This study duplicates the methods used to model the municipal outfalls in the Māmala Bay Study Report (Roberts, MB-4) in order to allow direct comparison of results. The identical numerical model was therefore used for nearfield plume behavior calculations, and similar methods were used to model the farfield plume behavior and resultant impacts. The cumulative impacts were calculated by modeling the movement of the wastewater plume and calculating the percent occurrence, or visitation frequency, at a given location.

2.3 Near Field Model

The near field behavior of the wastewater plume is dependent upon the effluent discharge volume, the length and depth of the diffuser, and the prevailing currents and density stratification. Initial mixing occurs due to the effects of momentum and buoyancy as effluent is discharged, and subsequent entrainment and turbulent mixing of the effluent with the receiving water as the buoyant plume rises toward the surface. Rapid dilution occurs immediately after discharge from the diffuser, but decreases significantly after the momentum and buoyancy are dissipated. The plume rises until the mixture of effluent and receiving water reaches a level of neutral buoyancy and becomes stable within the water column. The dilution obtained at this point is called the initial dilution, and the processes

involved are simulated with the near field model. Following initial dilution, the plume drifts with prevailing currents and is further diluted by oceanic turbulence. This subsequent mixing is not of the same magnitude as the initial dilution, and the different processes involved are simulated with the far field model.

The near field numerical model used in this study to simulate initial dilution is called RSB (Roberts, Snyder, and Baumgartner, 1989abc). It is EPA approved, and was used by Roberts for the Māmala Bay Study (MB-4). RSB is based upon extensive experimental studies on multiport diffusers in flowing density-stratified currents, and includes a wide range of jet momentum and buoyancy fluxes, port spacings, stratifications, and current speeds and directions. Previous models only allowed currents perpendicular to the diffuser, and parallel components were neglected. Parallel currents are included in RSB, which is an important consideration for modeling the outfalls in Māmala Bay. Model RSB is probably the best computer model available for modeling near field plume characteristics. D.W. Pritchard, a widely recognized pioneer researcher in coastal and estuarine processes, reviewed the Māmala Bay Study plume modeling study (MB-4) as part of the the peer review process, and described RSB as a state-of-the-art model (Māmala Bay Study, Appendix II, 1996).

The plume dynamics modeled in RSB assume that jet dynamics and plume buoyancy are the most important physical processes involved. The model is limited in that it is based upon linear density stratifications only, and is also based upon a uniform current in the water column. The effect of vertical velocity shear on the plume dynamics is not well known, however experiments in the Māmala Bay Study by Roberts (MB-4) suggest that the density profile is of greater importance than current shear in governing plume behavior. For this study, the mid-depth velocity measured by the ADCP is used in the plume model.

2.4 Far Field Model

As the plume stabilizes in the water column, it creates a wastewater field that moves with ambient currents, and becomes diffused by oceanic turbulence. It is typically assumed that the process involved follows the "4/3 power law," in which Brooks' (1960) solution to the diffusion equation is used to calculate the decay of peak concentration for a continuous line source in a steady current.

The minimum dilution of the wastefield at any location is the product of the minimum initial dilution S_i and the far field dilution, S_f:

$$S_m = S_i \times S_f \tag{1}$$

The concentration of a trace parameter at any location is given by:

$$c = \frac{c_0}{S_m} \tag{2}$$

where c_0 is the initial concentration of the tracer in the undiluted effluent.

The minimum dilution establishes the maximum concentration of a trace parameter, and is useful for predicting extreme effects such as from highly toxic substances. However, chronic impacts from effluent discharges are due to long term exposure and are more effectively predicted by estimating time-averaged contaminant concentrations using the harmonic average dilution, S_h:

$$S_h = \frac{1}{\frac{1}{n}\sum_{i=1}^{n}\frac{1}{S_i}} \tag{3}$$

where S_i is the dilution at any location at time step i.

The harmonic average dilution at a particular location x is approximated by,

$$S_h(x) = \frac{S_m(x)}{\nu(x)} \tag{4}$$

where ν is the frequency of occurrence, or visitation frequency, at location x.

2.5 Visitation Frequency

The visitation frequency calculations are a way of determining the cumulative impacts of the wastewater field on any particular location of interest, including the shoreline. The wastewater field is assumed to move and diffuse in response to currents measured during the oceanographic studies. This type of study is accomplished by following the path of discrete samplings of the effluent. For example, a sample or "puff" of effluent, s_i, where i

$= 1$ to n, released at time $t(s_i) = 0$ is moved, or advected, by the local current to a new location. For modeling purposes the geometric shape of the puff is a square with sides equal to the diffuser length. Time steps for the advection are based upon the sampling rate of the oceanographic data, in this case 20 minute intervals. At every time step, a new puff is released and subsequently followed for the duration of interest. If the duration of interest is 12 hours, the approximate period of the semi-diurnal tide, then the final sampling of s_i occurs at $t(s_i) = 12$ hrs. This is the duration for which a single puff is followed. However, the number of puffs followed, n, is dependant upon the sampling rate and the record length of interest of the oceanographic time series data. The record of interest may be, for example, weekly, monthly, seasonal, or annual.

The movement of the puffs can be summarized, following Roberts (Māmala Bay Study, MB-4) by:

$$x_{j+1}(s_i) = x_j(s_i) + u(x,t)\Delta t \tag{5}$$

where x_j is the initial location of the puff center, and $u(x,t)$ is the local velocity at position x_j and time t, and Δt is the time interval equal to the sampling rate of the current measurements. Equation 5 calculates the advection of the puff by the local current to a new location for each time step. After the duration of interest T for a puff released at time t_0, the location of the puff is given by:

$$x_T = x_{t_0} + \sum_{t=t_0}^{T} u(x,t)\Delta t \tag{6}$$

If one can imagine the ocean surface divided into a grid, the probability of effluent reaching a particular grid node can be directly related to the number of times a discretized puff "visits", or overlays the grid node. The summation of all visits for the duration of interest and for the record length of interest divided by the total number of releases will give the visitation frequency. The methodology used in this impact analysis is derived from Koh (1988). He describes the long term impacts as:

$$g(t) = g(t - \Delta t) + (1 - g(t - \Delta t))f(t) \tag{7}$$

where, $g(t)$ = cumulative visitation frequency during time t
$f(t)$ = visitation frequency at time t

To compare the present study with the Māmala Bay Study (MB-4), the full year oceanographic record was divided into winter and summer seasons. Individual puffs were followed for durations of 12 hours and 24 hours, the diurnal and semi-diurnal tide frequencies. In addition, the seasonal visitation frequency was determined in order to calculate the seasonal harmonic average dilution using Equation 3.

2.6 Oceanographic Data

In situ oceanographic data were taken on a year-long schedule, from January 24, 1995 to December 1, 1996. Data acquisition was briefly interrupted for servicing of the instruments approximately every two to three months. The ADCP measures the current speed and direction in five overlapping layers through the water column: 0 through 12 meters, 6 through 17 meters, 12 through 23 meters, 17 through 29 meters, and 23 through 35 meters. Measurements were obtained at 20 minute sampling intervals; each data point averages a 10 minute sampling period at a sample rate of 10 seconds. A thermistor string deployed on a taught line mooring in the same location as the ADCP measured the temperature at three water column depths: 14.6 meters, 26.8 meters, and 37.5 meters.

2.7 Effluent Flow Rate and Fluid Density

A typical daily flow rate was calculated from data provided by the WWTP at Fort Kamehameha. Twenty days of data were averaged to give flow rates at two hour intervals. Flow rates were increased by 36 percent in order to correspond to the plant design flow rate of 13 MGD.

Effluent salinity, from which fluid density was calculated, was estimated from a year of chloride data, measured daily. A salinity value of 9 ppt was used for the winter months, and 10.1 ppt used for the summer months.

2.8 Integrated Model Procedure

The numerical model used in this study is an integration of the near field model RSB (Roberts *et al.*, 1989abc), far field dilution based upon the 4/3 power law (Brooks, 1960),

and far field impact analysis, or visitation frequency, based upon the work of Koh (1988). It is essentially identical to the methods of Roberts in the Māmala Bay Study (MB-4), and similar to those of Noda (1993). This study has a more complete year-long oceanographic data set than the Māmala Bay Study, which suffered from current meter failures. Also, Noda (1993) extrapolated the wind effect on upper water column transport using wind data from Honolulu Airport. The use of an ADCP in this study allows direct measurement of currents in the upper water column, and includes the effect of wind. The Māmala Bay Study used four current meter sites, and interpolated velocities between the sites. This study uses one current meter site as the region of concern is much more restricted.

The time step procedure uses the oceanographic data for calculations at 20 minute intervals. The initial dilution and plume entrapment depth are calculated with model RSB using mid-depth (12 - 23 meters) current speed and direction, and a density profile calculated from the thermistor data. Following procedures of the Māmala Bay Study (MB-4), far field simulations were then performed on surfaced plumes. Surfaced plumes travel with relatively fast moving surface currents, and are therefore more likely to impinge on the shoreline than submerged plumes travelling with deeper, slower currents.

The surface layer measurement (0 - 12 meters) of the ADCP is used to predict the movement of the far field plume. Visitation frequencies are calculated using a grid node interval of 500 meters.

3.0 RESULTS

3.1 Introduction

Near field and far field plume dilution modeling, and visitation frequency modeling were accomplished for two diffuser configurations for surfacing plumes. In Case 1, the diffuser is 200 meters in length and is located in 46 meters of water. For Case 2 the diffuser is in 21 meters of water, with a length of 400 meters. Model durations were divided into winter and summer seasons following the methods of the Māmala Bay Study (MB-4). The winter season extends from November through March, while the summer season extends from March through October. Data acquisition periods are shown below:

Winter	Summer
1/24/95 - 3/18/95	3/31/95 - 5/21/95
10/27/95 - 12/1/95	5/26/95 - 6/30/95
	7/26/95 - 10/24/95

Plume rise and dilution were plotted for the entire oceanographic time series. Plots were generated of the harmonic average dilution and both 12-hour and 24-hour visitation frequencies for both diffuser alternatives during the summer and winter seasons.

3.2 Plume Transport and Visitation Frequency

There is seasonal variation in transport of the outfall plume that is shown by the plots of visitation frequency. The plots show two primary modes of plume transport: shore parallel, primarily to the west, and offshore to the south. Westward transport is more pronounced during the summer season due to prevailing northeast trade winds. During the winter, trade winds diminish and winds can be calm or come from the south. Transport is more diffuse and variable at this time, with eastward transport more evident.

The visitation frequency plots show the probability of plume occurrence over the course of a semi-diurnal tide cycle (12 hours) and a diurnal tide cycle (24 hours) for the summer and winter seasons. The results for both cycles are similar in all cases, with a slightly elevated probability of occurrence for the diurnal cycle. Figure 3 is the 24-hour visitation frequency for Case 1 in the summer, and shows the strong shore-parallel westward transport. Figure 4, the 24-hour visitation frequency for Case 1 in the winter, shows the effects of weaker shore-parallel westward transport, with transport more diffuse in general and showing a strong easterly component. Figures 5 and 6 are corresponding plots for Case 2. 12-hour visitation frequency plots are contained in the appendix.

The worst case for shoreline impacts is for Case 2 winter (Figure 6). There is a 16% probability of occurrence of effluent at the southeast corner of the Reef Runway shoreline, and 4 to 6 percent probability of occurrence in Hickam Harbor. Probability of effluent occurrence within the Class 2 Inland Estuary waters of Pearl Harbor is about 3 percent, with dilution greater than 5000:1, as shown later in Figure 9. For Case 1 winter, the probability of occurrence at the corner of the Reef Runway is about 4 percent, and the probability of occurrence within the Class 2 waters of Pearl Harbor is about 1 percent.

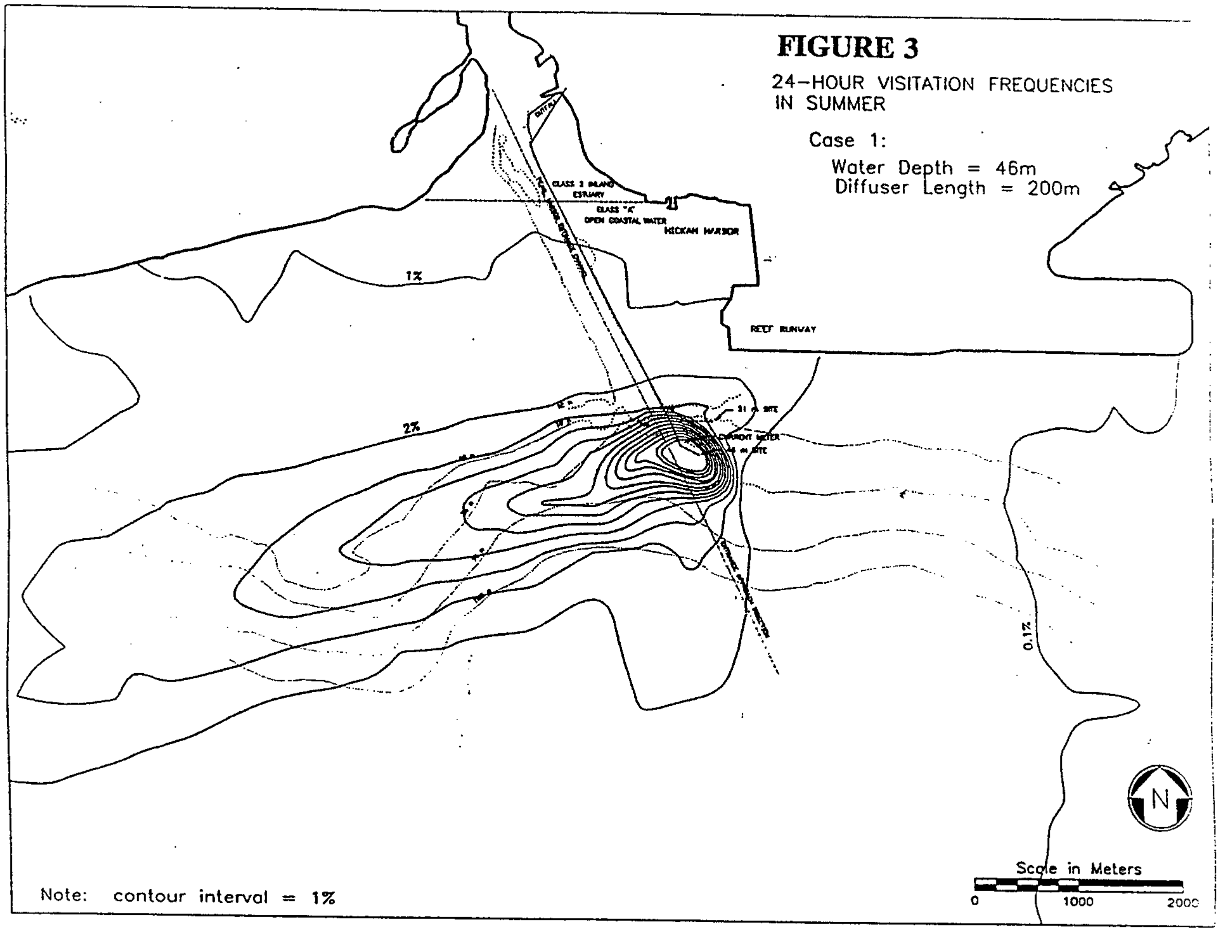


FIGURE 3

24–HOUR VISITATION FREQUENCIES IN SUMMER

Case 1:
Water Depth = 46m
Diffuser Length = 200m

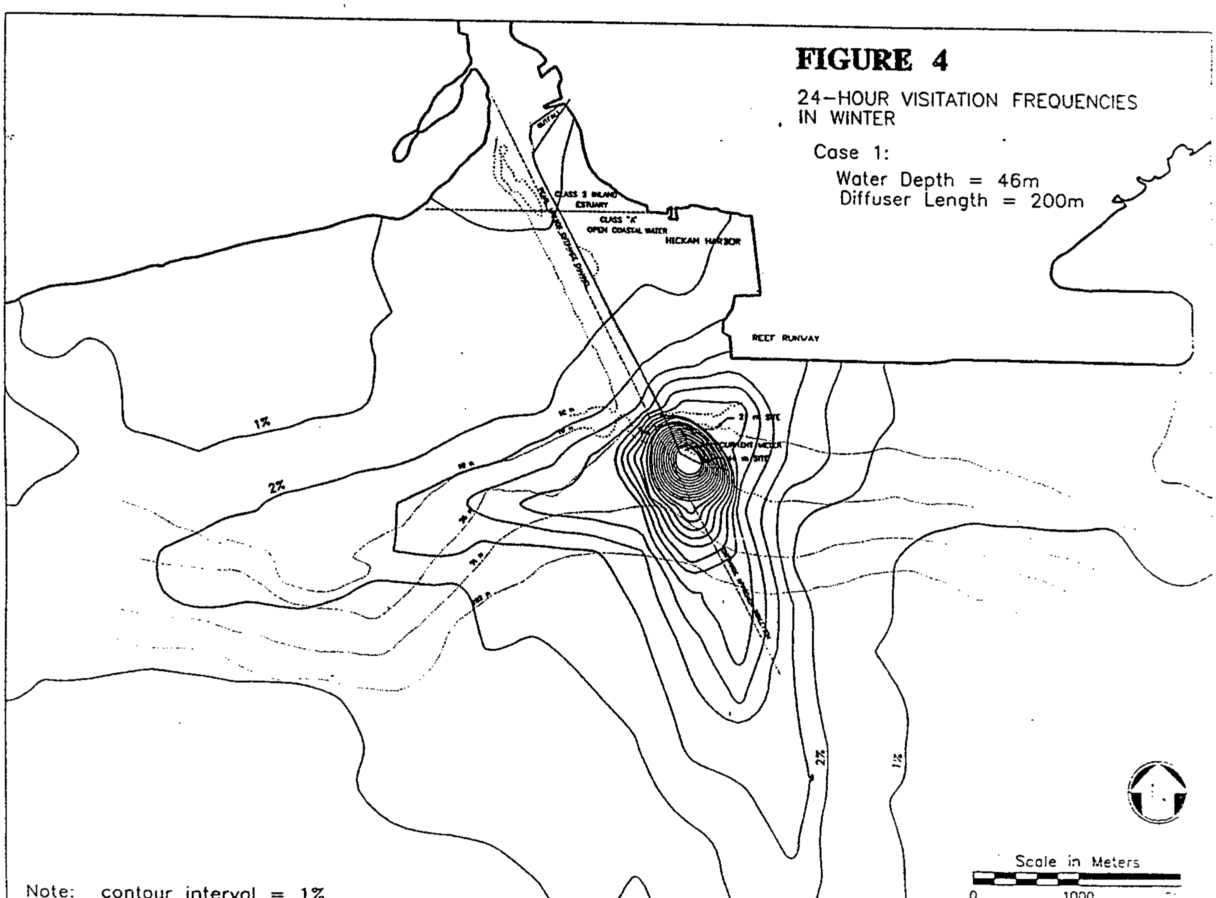


FIGURE 4

24–HOUR VISITATION FREQUENCIES IN WINTER

Case 1:
Water Depth = 46m
Diffuser Length = 200m

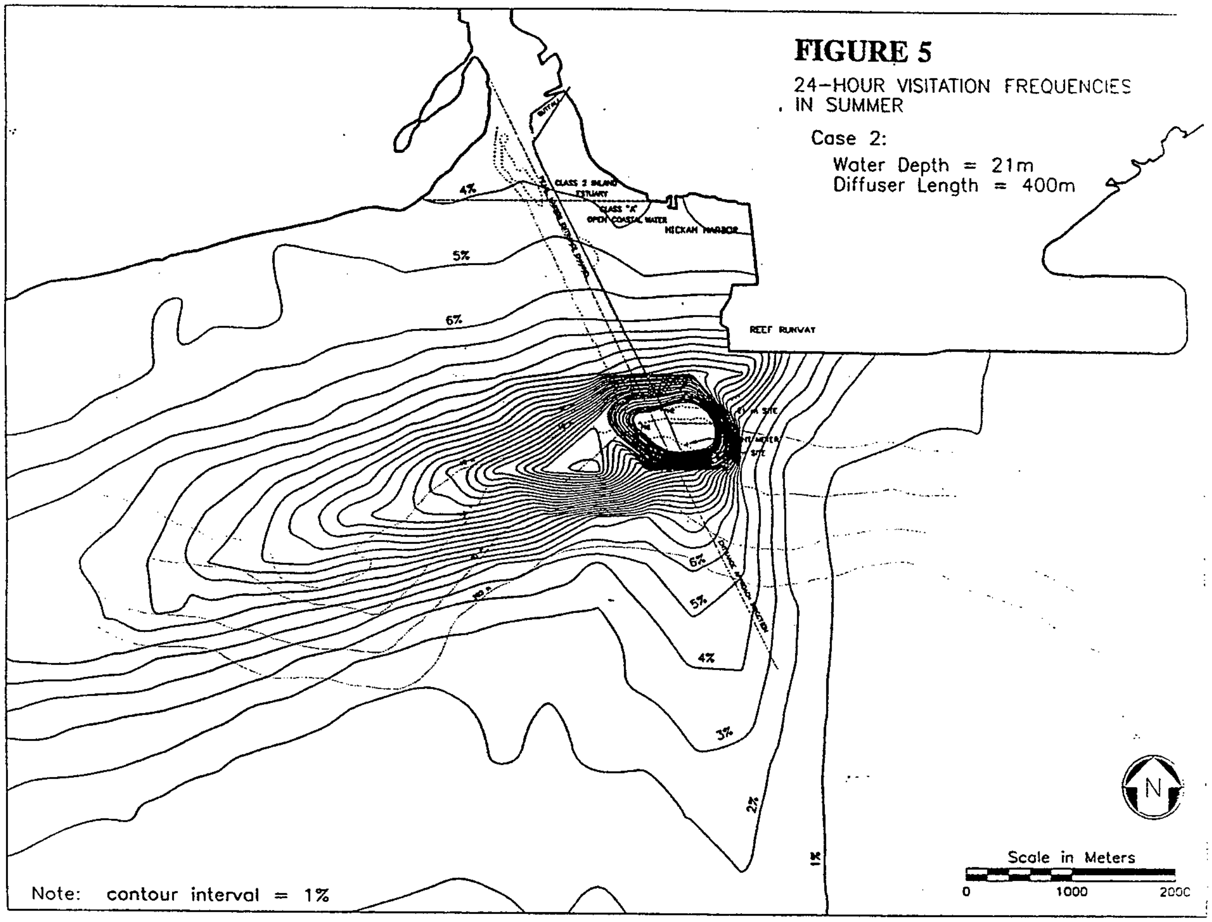


FIGURE 5

24–HOUR VISITATION FREQUENCIES IN SUMMER

Case 2:

Water Depth = 21m
Diffuser Length = 400m

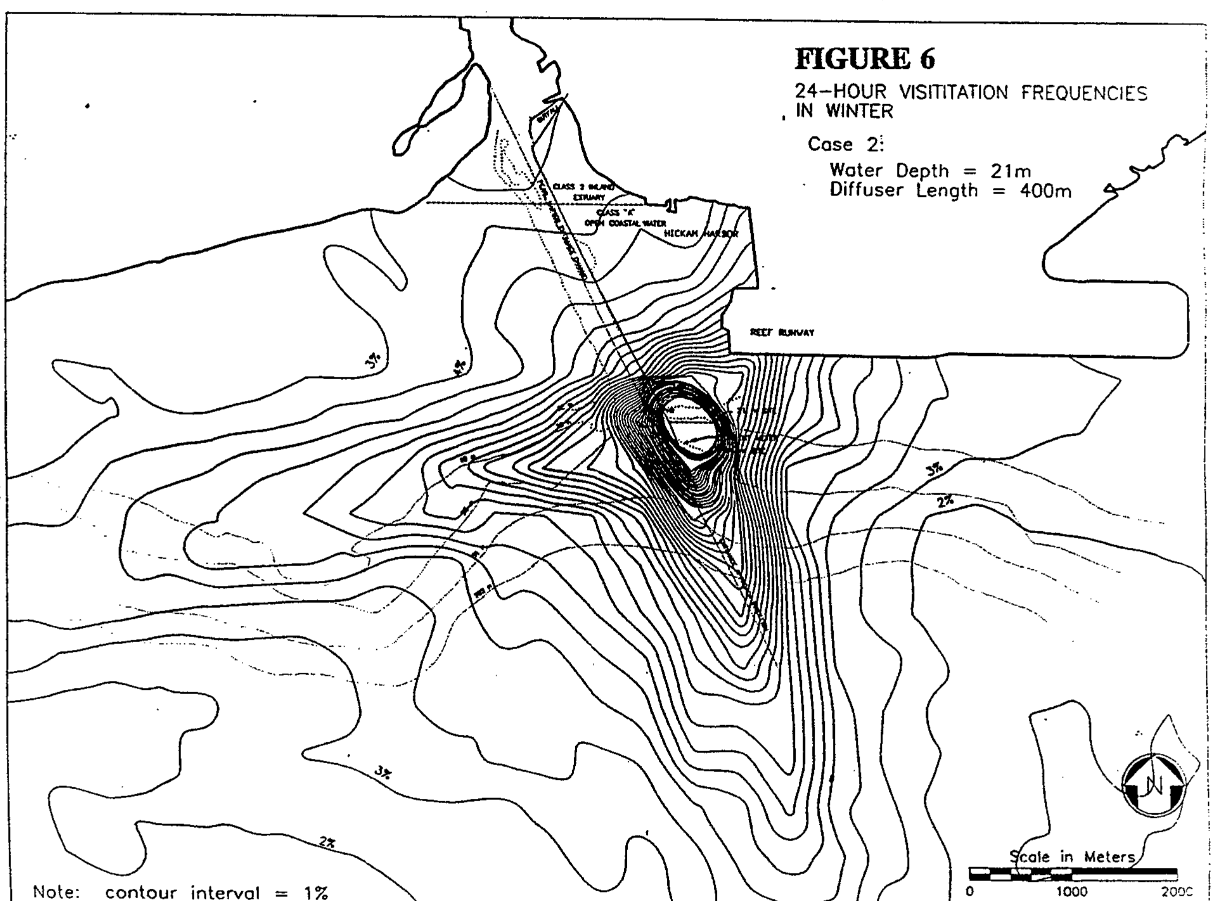


FIGURE 6

24–HOUR VISITATION FREQUENCIES IN WINTER

Case 2:

Water Depth = 21m
Diffuser Length = 400m

3.3 Time Series Data: Plume Rise and Dilution

Initial dilution of the wastewater plume and plume rise height for Case 1 and Case 2 using the complete year-long oceanographic data set are plotted and contained in the appendix. These plots show the complex nature and variability of plume behavior and the dilution process, and also give a graphic illustration of plume rise, entrapment, and surfacing over time. In particular, the Case 1 plots show pronounced seasonal variation, with the highest incidences of plume surfacing occurring during the months of January and February, and extended plume submergence occurring during the summer months of August and September. The wastewater plume surfaced 71.4 percent of the time during the winter, and 46.5 percent of the time during the summer for Case 1, with the diffuser at the 46 meter depth. Increased incidence of plume surfacing during the winter was also observed in the Māmala Bay Study (MB-4) and Noda (1993), and is due to the lack of density stratification in the water column. Increased stratification during the summer decreases the incidence of plume surfacing.

Results for Case 2 at the 21 meter depth show less variability, with the plume surfacing 99.6 percent of the time in the winter and 95.2 percent of the time in the summer. A summary of plume statistics derived from the model is presented in Table 1.

Table 1. Near Field Plume Statistics

		Frequency (%)	Lowest Dilution	Highest Dilution	Average Dilution	Average Rise Height (m)
Case 1						
Submerged	Winter	28.6	126	1504	487	34.8
	Summer	53.5	111	1602	402	30.0
Surfacing	Winter	71.4	346	1878	564	46
	Summer	46.5	342	1922	571	46
Case 2						
Submerged	Winter	0.4	215	757	527	17.8
	Summer	4.8	124	941	428	15.3
Surfacing	Winter	99.6	211	1178	417	21
	Summer	95.2	208	1243	432	21

An example plot from Case 1 during the spring (3/31 to 5/21) is shown in Figure 7 and illustrates the extreme variation in plume behavior. Neither plume rise nor plume dilution behave in a steady manner. Short term, oscillating plume behavior is probably due to short term changes in water column stratification influenced by the semi-diurnal tide, and diurnal changes in effluent flow. Long term changes in behavior are due to seasonal changes that include variations in wind and large scale changes in water mass characteristics. Figure 7 shows features of both winter and summer seasons. Periods of plume surfacing and high rise heights that occur during middle to late April are similar to the winter behavior of January and February. Extended periods of plume submergence and oscillating plume rise heights, seen at the beginning of April and during most of the month of May, are more typical of summer conditions that prevail in August and September. Periods of relatively high plume dilution typically coincide with a surfacing plume.

The complexity of oceanographic conditions and the corresponding variable plume behavior evident in the time series plots show the difficulty involved in trying to model the outfall impact. Static models can not be used to give accurate long-term, chronic impacts. The time integrated model used here, with appropiate and complete oceanographic data, is perhaps the only valid approach at present.

3.4 Harmonic Average Dilution

The long term, chronic, effects from the outfall are best illustrated by plots of the seasonal harmonic dilution . Plots of harmonic dilution for the winter season for Case 1 and Case 2 are shown in Figures 8 and 9. Comparison of Case 1 and Case 2 shows that, for any point in the immediate outfall vicinity, dilution for Case 1 is approximately 3 to 5 times higher than that for Case 2. Figures 10 and 11 are the harmonic dilution for Case 1 and Case 2 in the summer. As with the winter plots, Case 1 dilution is 3 to 5 times greater for any location than is the Case 2 dilution.

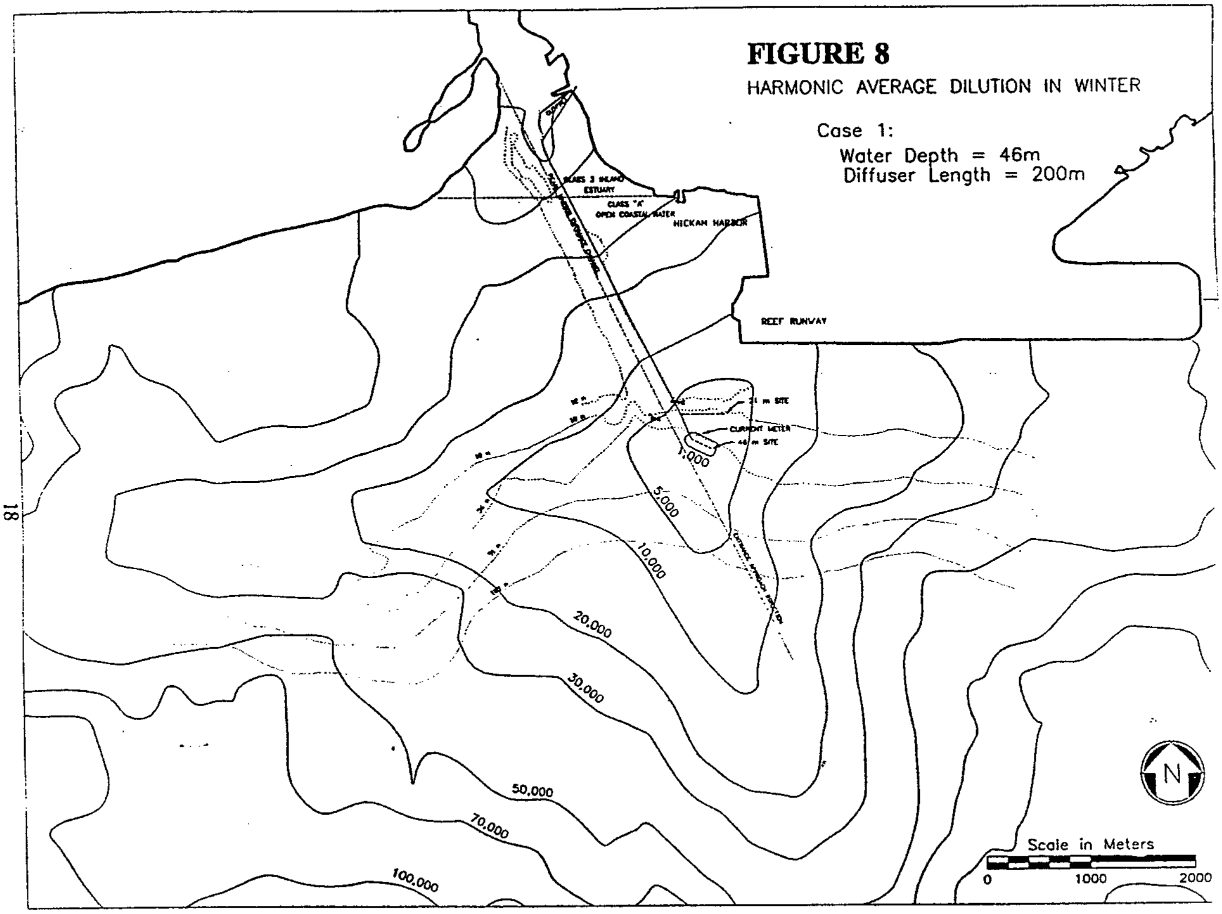


FIGURE 8

HARMONIC AVERAGE DILUTION IN WINTER

Case 1:
Water Depth = 46m
Diffuser Length = 200m

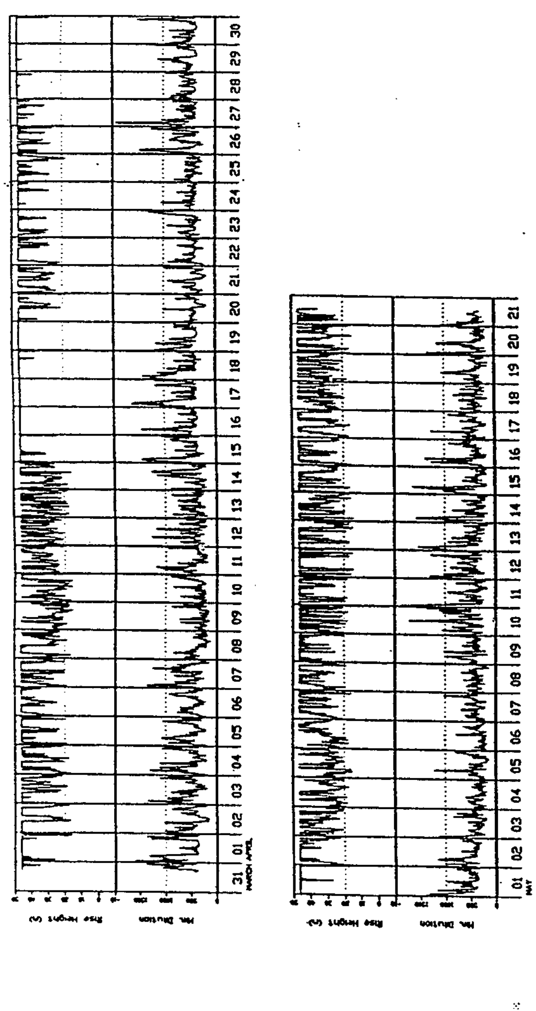


FIGURE 7

NEAR FIELD PLUME RISE HEIGHT AND MINIMUM DILUTION

Case 1: Water Depth = 46m
Diffuser Length = 200m

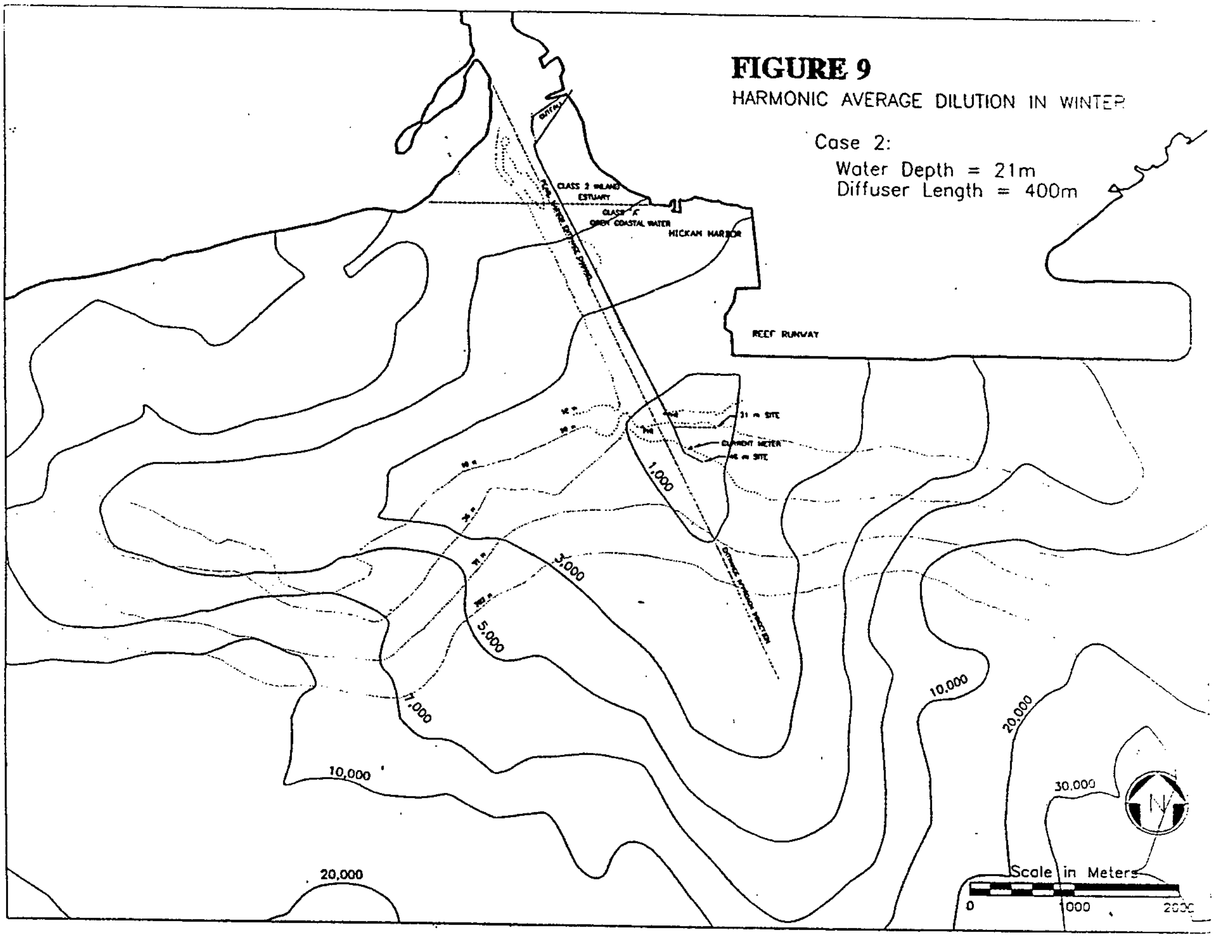


FIGURE 9

HARMONIC AVERAGE DILUTION IN WINTER

Case 2:
Water Depth = 21m
Diffuser Length = 400m

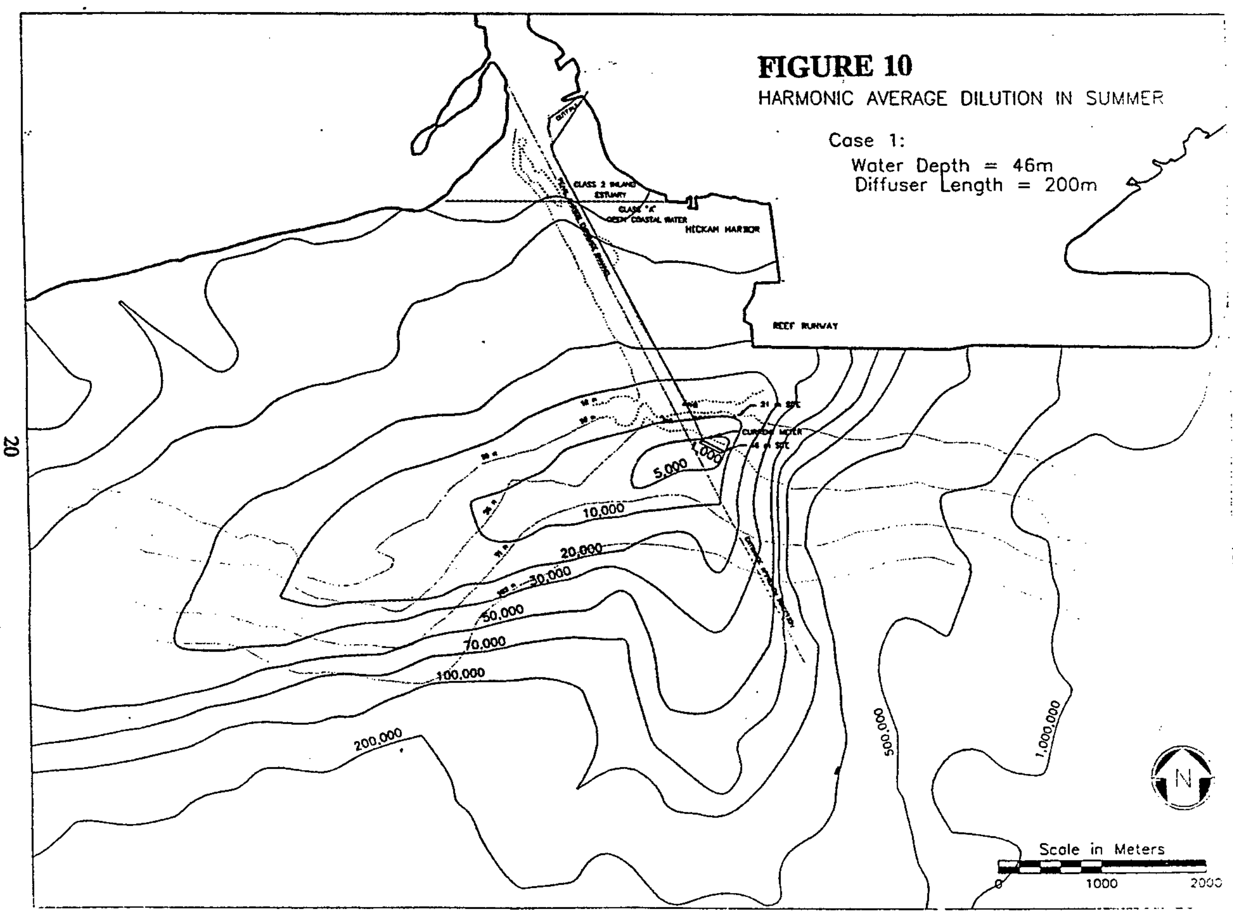


FIGURE 10

HARMONIC AVERAGE DILUTION IN SUMMER

Case 1:
Water Depth = 46m
Diffuser Length = 200m

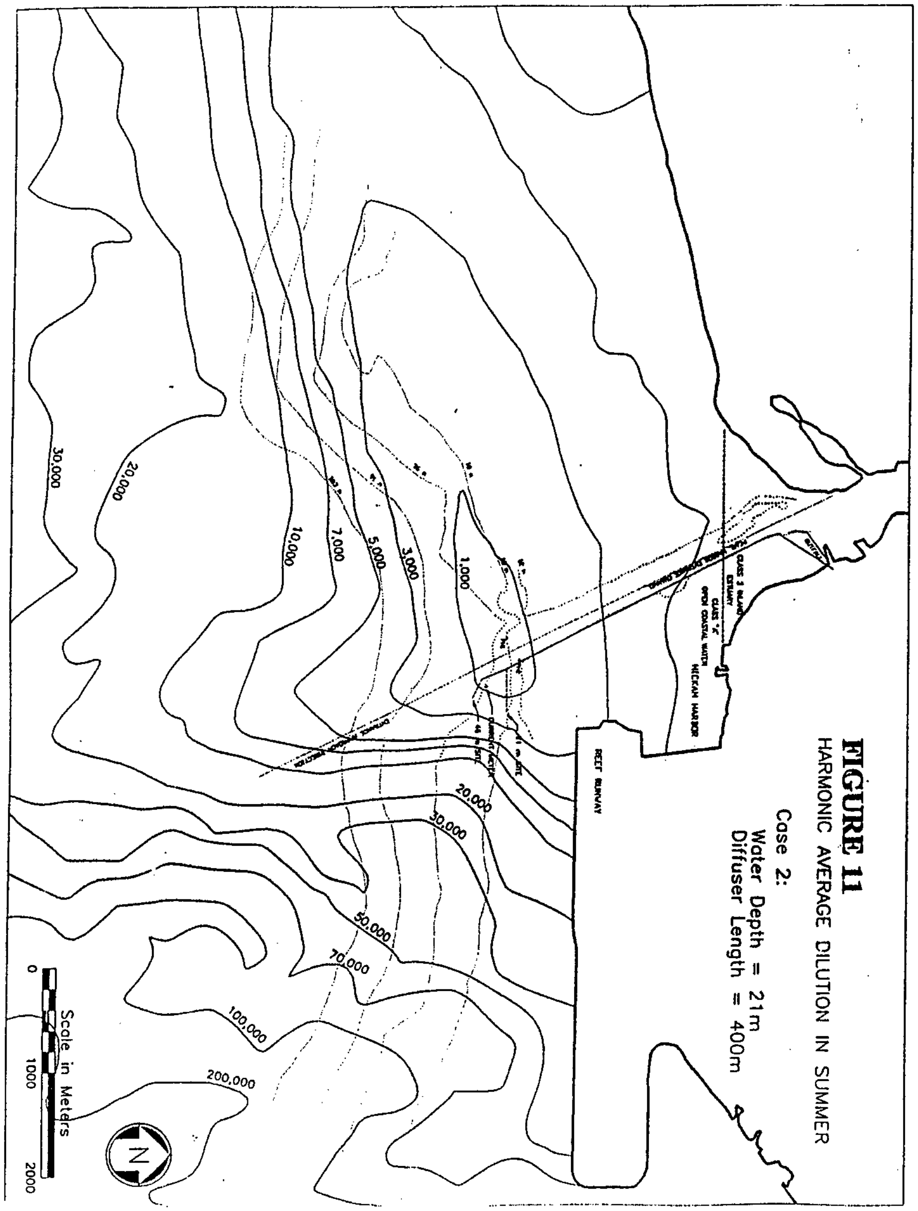


FIGURE 11
HARMONIC AVERAGE DILUTION IN SUMMER

Comparison of the winter plots with the summer plots show the effect of weaker and more variable transport during the winter. The summer plots have strong dilution gradients to the east and to the south as the plume moves predominantly westward. The winter plots are more diffuse, with effluent spread more evenly around the diffuser.

The dilution required to meet State of Hawai'i Department of Health (DOH) water quality standards is approximately 1200:1, using nitrate as the critical parameter (SSFM Engineers, Inc., 1996). Regions with less dilution will not meet the Class A Water Quality Standards. The 1000:1 dilution contours shown on the harmonic average dilution plots (Figures 8 through 11) approximate the regulatory zone of mixing. For Case 2 the 1000:1 contour is close to the southwest corner of the Reef Runway, and it is therefore probable that water quality standards will be exceeded at this location, especially during the winter. Dilution increases to 3000:1 inside Hickam Harbor. For Case 1, dilution values are close to 10000:1 at the Reef Runway and 20000:1 inside Hickam Harbor.

3.5 Combined Harmonic Average Dilution

Figures 12 through 15 are comprehensive plots of the harmonic average dilution in Māmala Bay, showing the combined effects of all three outfalls: Sand Island, Honouliuli, and the proposed Fort Kamehameha extension. The data for Sand Island and Honouliuli were taken from the Māmala Bay Study (MB-4). There were no data available for the summer season for the Honouliuli outfall. Dilution contours from each outfall are overlaid in the figures.

Table 2 lists the nutrient concentrations of the effluents at the three plants. The concentrations from the Sand Island and Honouliuli WWTP's are from the Māmala Bay Study, MB-3, and are averages of data taken for several previous studies. The lowest overlapping dilution contours from the three outfalls from each of the plots, Figures 12 through 15, are presented in Table 3.

FIGURE 12

FORT KAMEHAMEHA OUTFALL
HARMONIC AVERAGE DILUTION
IN MAMALA BAY

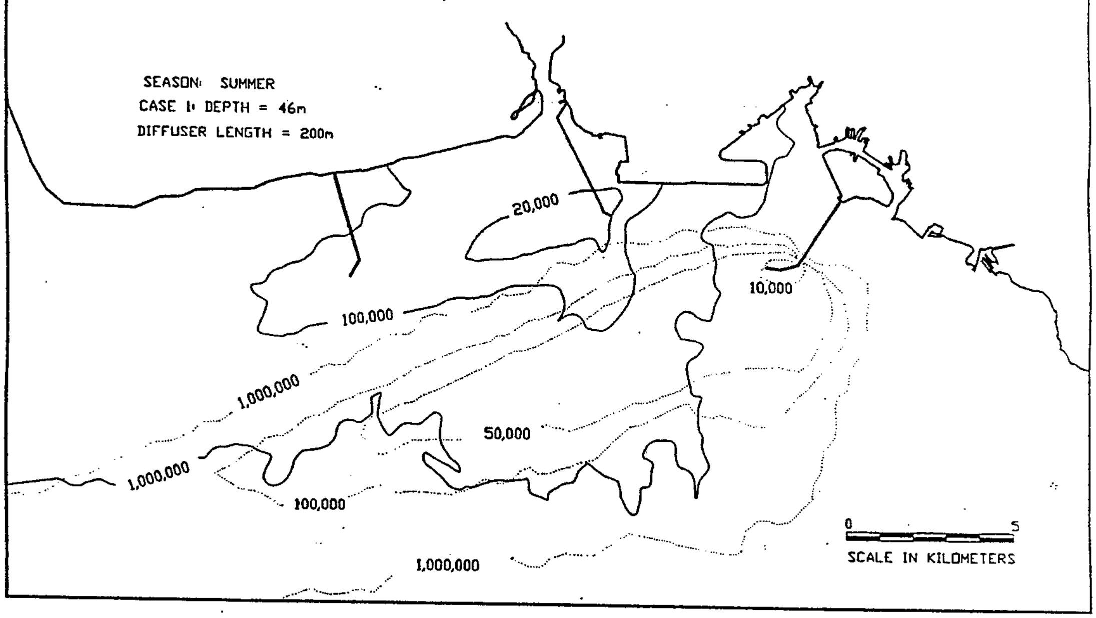


FIGURE 13

FORT KAMEHAMEHA OUTFALL
HARMONIC AVERAGE DILUTION
IN MAMALA BAY

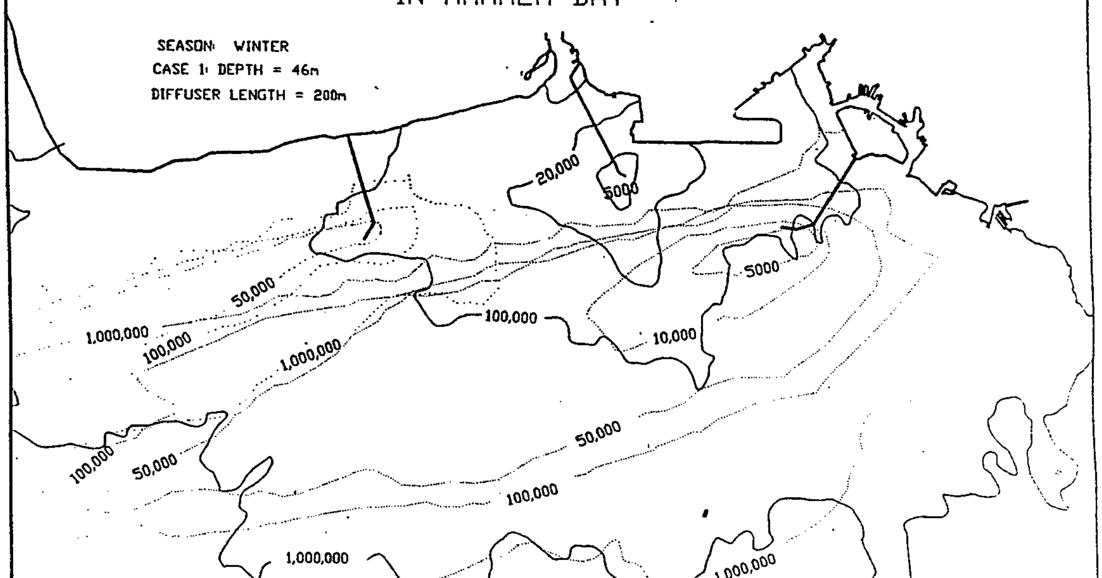


FIGURE 14
FORT KAMEHAMEHA OUTFALL
HARMONIC AVERAGE DILUTION
IN MAMALA BAY

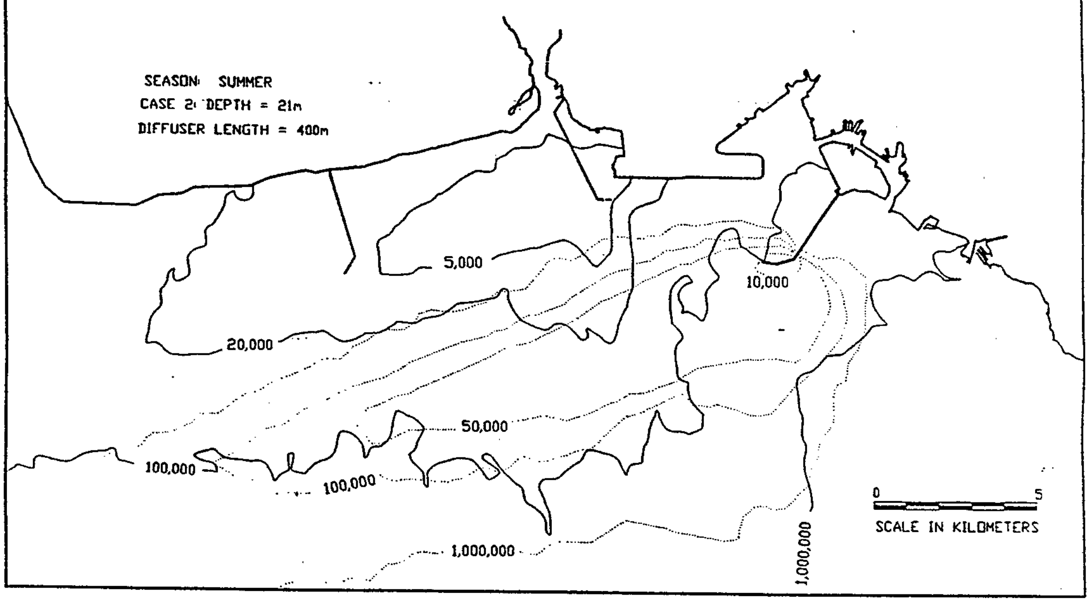


FIGURE 15
FORT KAMEHAMEHA OUTFALL
HARMONIC AVERAGE DILUTION
IN MAMALA BAY

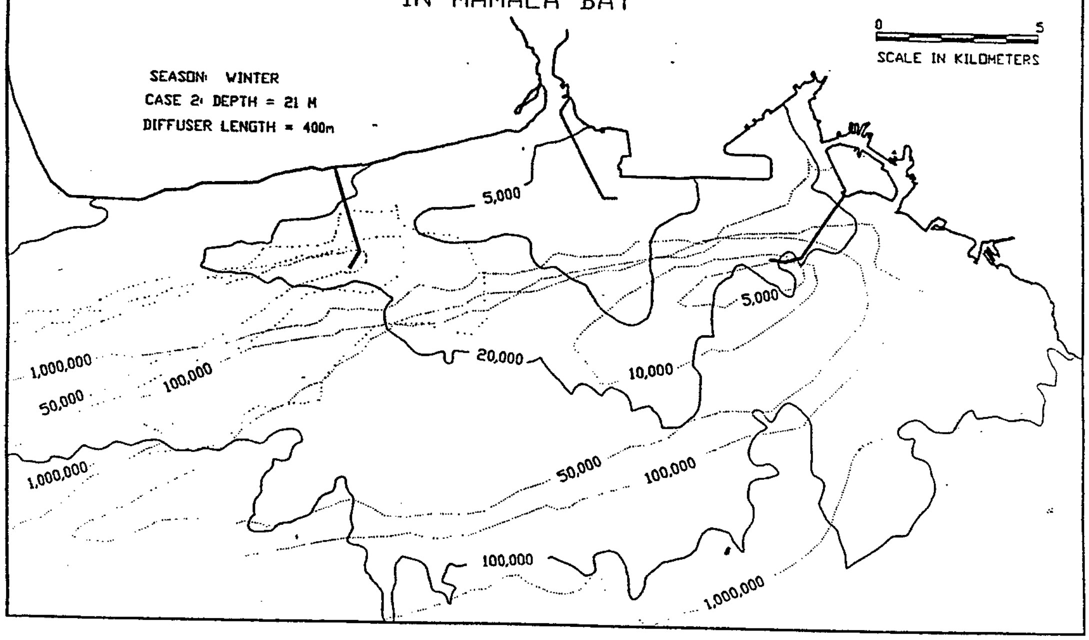


Table 2. Māmala Bay Wastewater Treatment Plants Nutrient Concentrations

	Sand Island	Honouliuli	Fort Kamehameha
NH_4	14,300	18,500	1,600
NO_2/NO_3	80	55	5000
TN	19,000	24,100	8,200
TP	2,750	3,700	1,400
Flow Rate	72 MGD ($31.5\ m^3/s$)	24 MGD ($10.5\ m^3/s$)	13 MGD ($5.7\ m^3/s$)

Notes: Concentrations in $\mu g/L$; Sand Island and Honouliuli data are derived from the Māmala Bay Study, MB-3, Table 4.2; Fort Kamehameha data were provided by the Navy, from SSFM Engineers, Inc. (1996).

Table 3. Māmala Bay Plume Mixing

Lowest Intersecting Dilution Contours:		Fort Kamehameha	Sand Island WWTP
Case 1	Winter	20,000	10,000
	Summer	100,000	50,000
Case 2	Winter	5000	10,000
	Summer	5000	1,000,000

The worst case of the combined effluents is a 5000:1 dilution contour from the WWTP at Fort Kamehameha that overlaps with a 10000:1 dilution contour from Sand Island for the Case 2 winter, shown in Figure 15. Using effluent concentration values from Table 2, the

combined effect of overlapping outfall plumes is listed in Table 4. Although the nitrate/nitrite nutrient concentration was found to be the critcal parameter for dilution calculations of the WWTP at Fort Kamehameha, the nitrate/nitrite concentrations of the Sand Island and Honouliuli effluents are low. Therefore total Phosphorus is used as the critical parameter for the combined dilution calculations in Table 4. The ambient total Phosphorus concentration is based upon water quality measurements listed in the oceanographic study (SSFM Engineers, Inc., 1996).

Table 4. Combined Concentrations of Total Phosphorus

Ambient Total Phosphorus Concentration	10.6 $\mu g/L$
Sand Island Plume Excess Total Phosphorus Concentration at 10000:1 Dilution	0.3 $\mu g/L$
Fort Kamehameha Plume Excess Total Phosphorus at 5000:1 Dilution	0.3 $\mu g/L$
Combined Total Phosphorus Concentration	10.9 $\mu g/L$
DOH Water Quality Standards	20 $\mu g/L$

The combined total Phosphorus concentration presented in Table 4 is calculated by combining and averaging the excess from the plumes and mixing with ambient water. The result of Table 4 shows that there are no interactions of significance between the three outfalls. By the time the plumes mix, dilution values are extremely high and concentrations essentially identical. The combined effect is less than 3% above ambient levels, and exceeds DOH water quality standards.

4.0 CONCLUSIONS

Model simulations have been completed that project the effect of the Fort Kamehameha waste water treatment plant outfall extension. Two outfall and diffuser alternatives were modeled; Case 1 uses a 200-meter long diffuser in 46-meters of water depth, and Case 2 uses a 400-meter long diffuser in 21-meters of water depth. The diffuser sites were chosen

of the time in the winter season, and 46.5 percent of the time in the summer season. The Case 2 plume surfaced virtually all of the time. Plume dilutions were generally lower in the winter season, although dilution is generally highest for a surfacing plume.

Results of the study show low visitation frequencies and high dilution rates for the Case 1 outfall configuration, and no chronic long term adverse impacts are predicted. The Case 2 outfall configuration will probably impact the shoreline at the southwest corner of the Reef Runway. The probability of effluent impacting the shore at this location is approximately 15 percent, and chronic dilution values are near 1000:1, meaning DOH water quality standards are likely to be exceeded at this location.

Combined impacts of all three outfalls in Māmala Bay are negligible. By the time the separate outfall plumes interact, dilution values are high and combined nutrient concentrations are only slightly above the background level.

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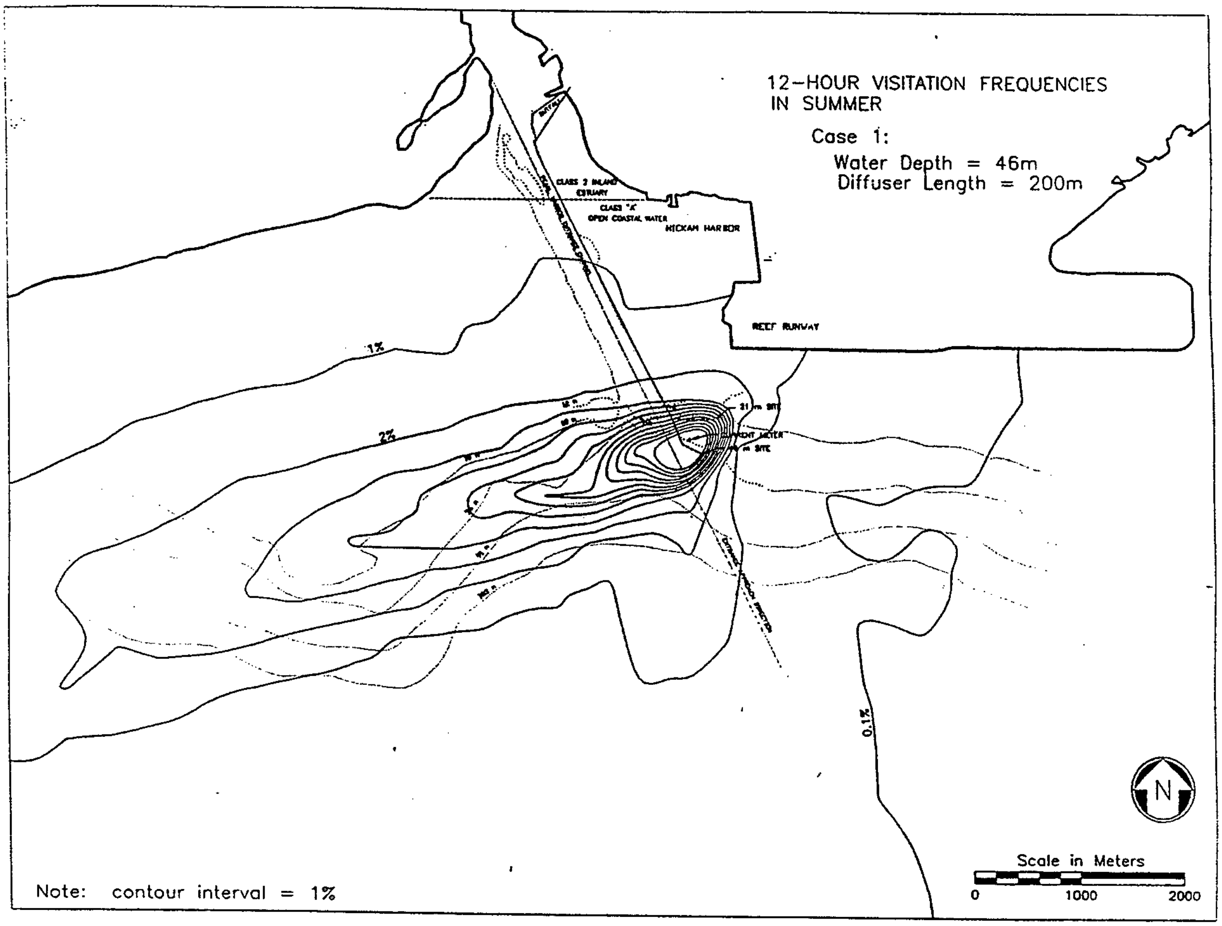
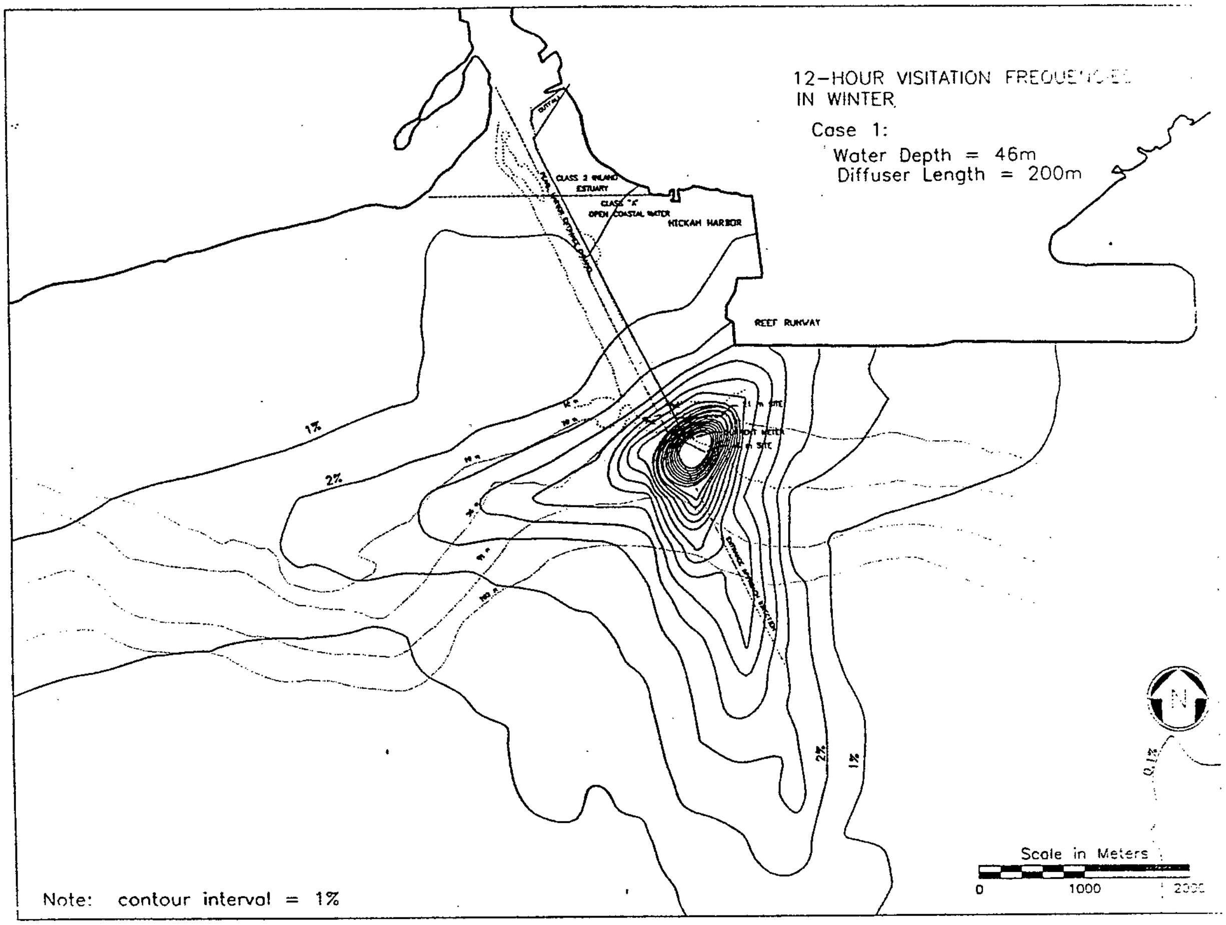
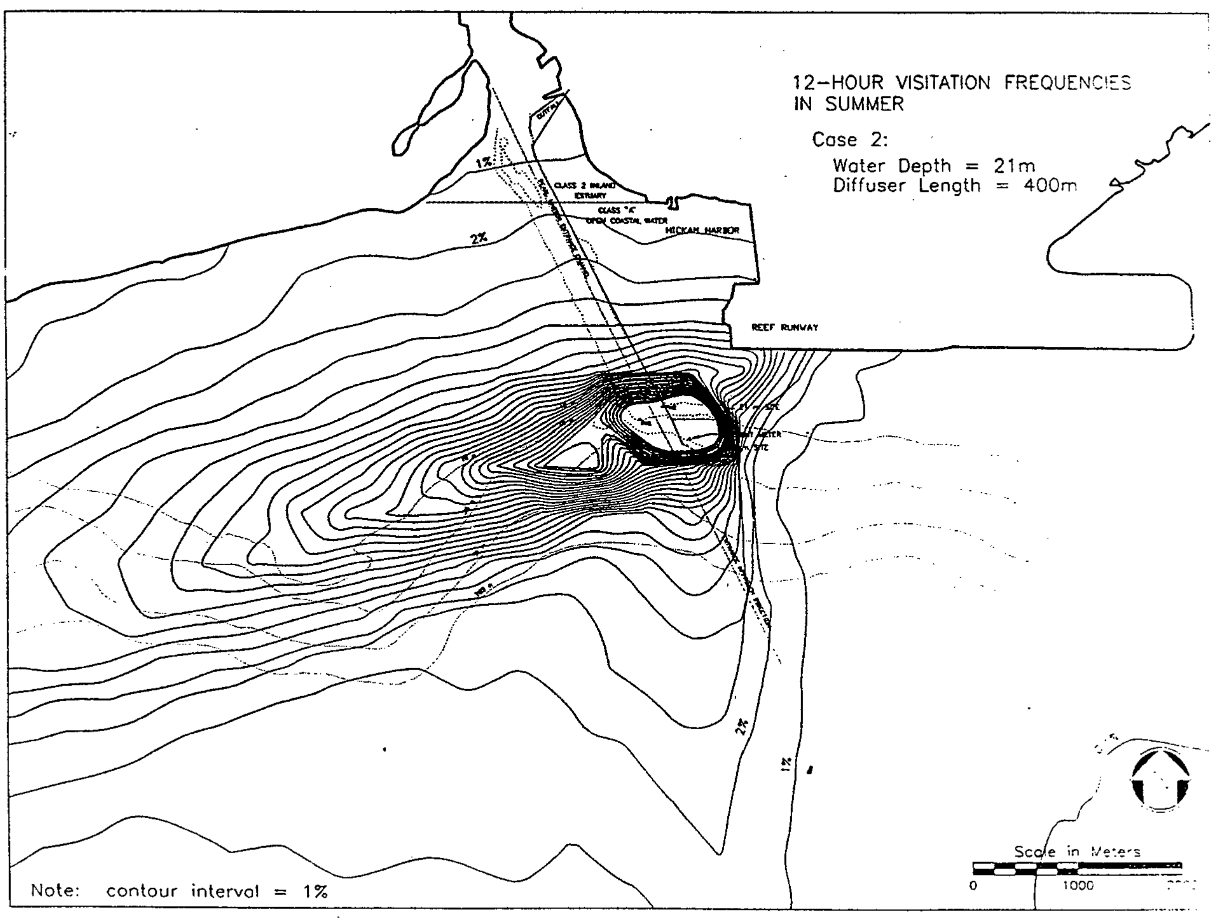


APPENDIX A-1

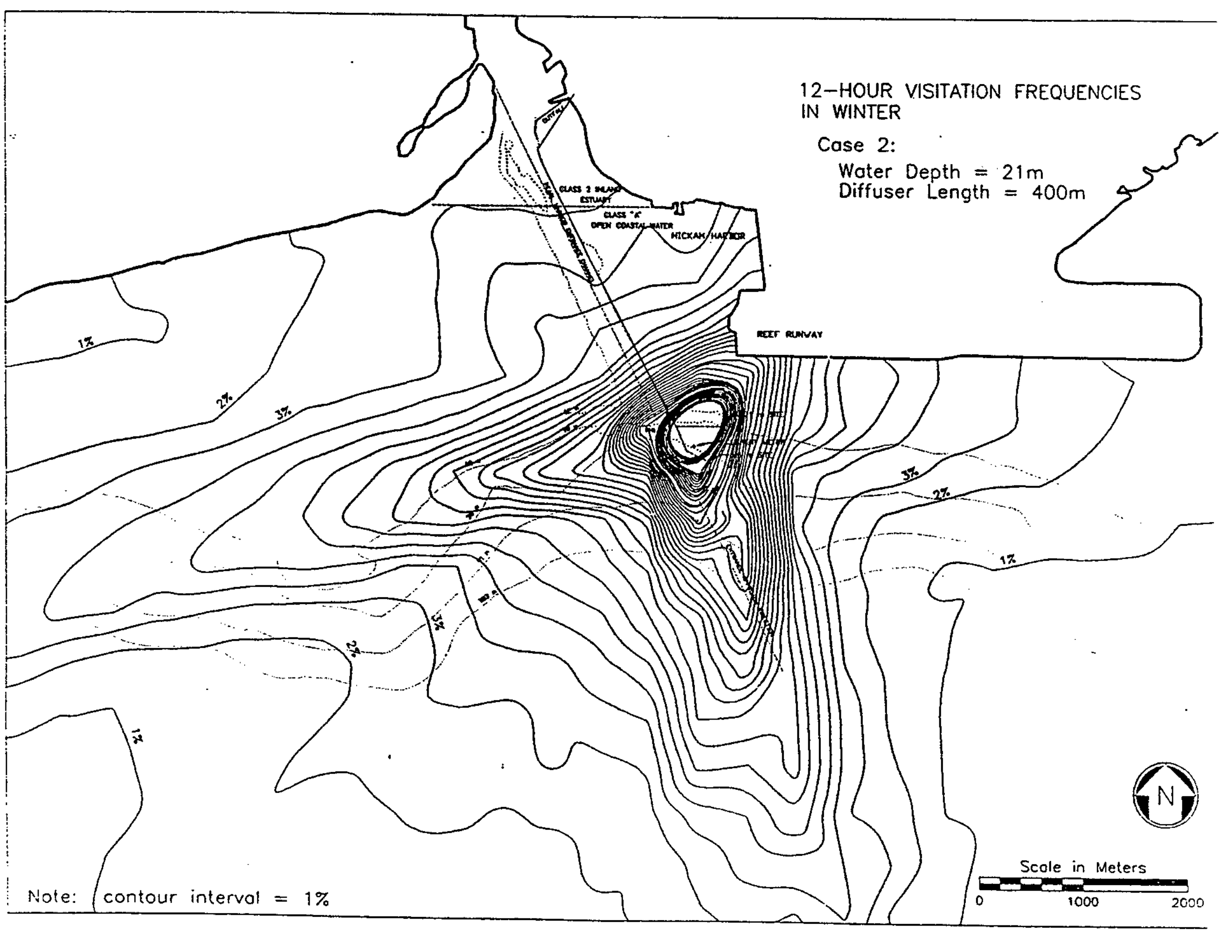
12-HOUR VISITATION FREQUENCIES

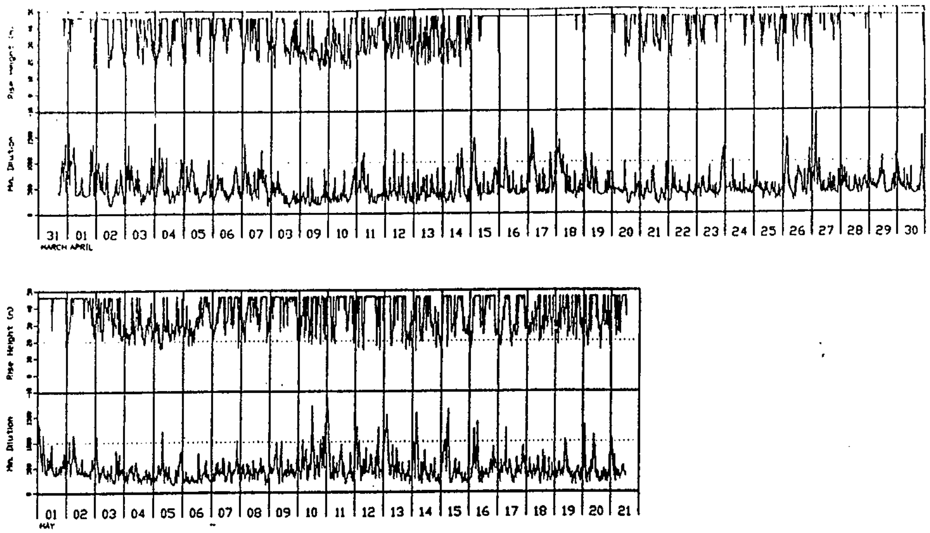

12-HOUR VISITATION FREQUENCIES IN WINTER
Case 1:
Water Depth = 46m
Diffuser Length = 200m
CLASS 2 INLAND ESTUARY
CLASS "A" OPEN COASTAL WATER
HICKAM HARBOR
REEF RUNWAY
1%
2%
Scale in Meters
0
1000
Note: contour interval = 1%


12-HOUR VISITATION FREQUENCIES IN SUMMER
Case 2:
Water Depth = 21m
Diffuser Length = 400m
CLASS 2 INLAND ESTUARY
CLASS "A" OPEN COASTAL WATER
HICKAM HARBOR
REEF RUNWAY
1%
2%
Scale in Meters
0
1000
Note: contour interval = 1%

APPENDIX A-2

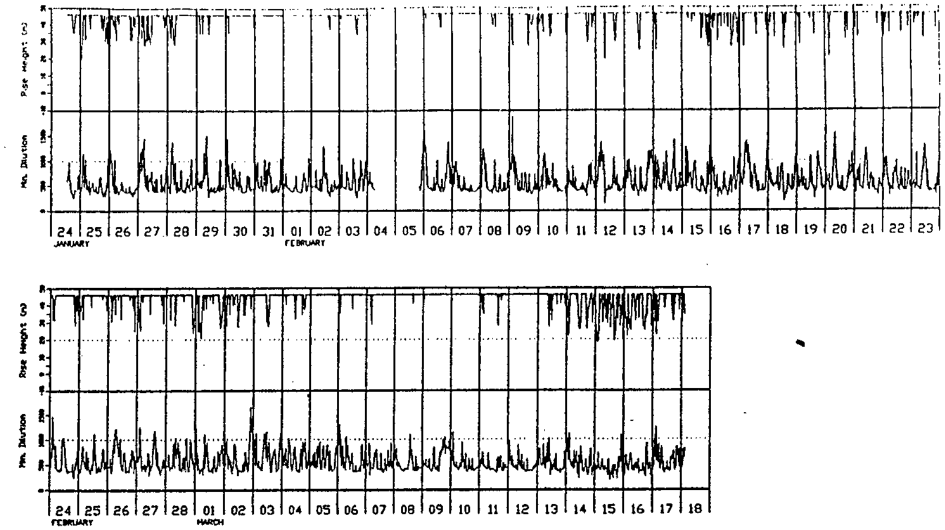
TIME SERIES DATE, CASE 1
PLUME RISE HEIGHT AND MINIMUM DILUTION





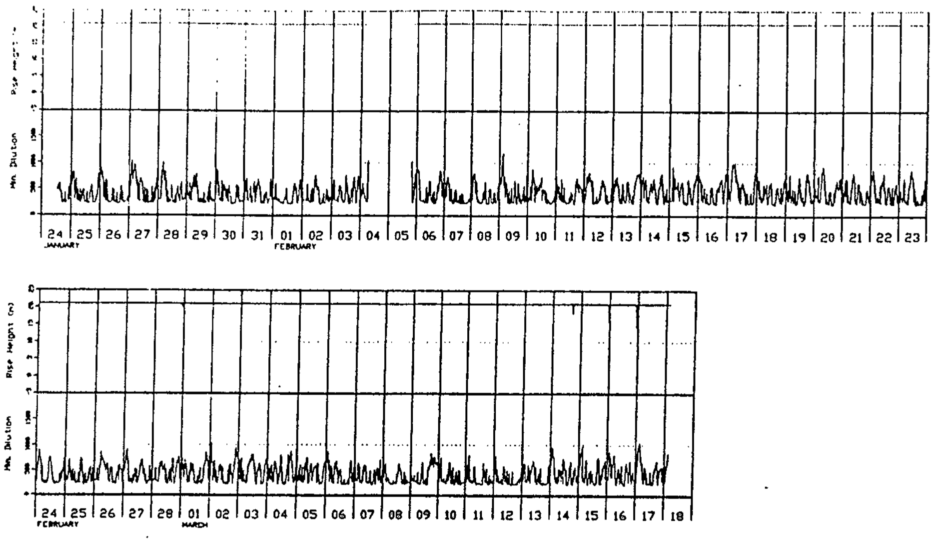
NEAR FIELD PLUME RISE HEIGHT AND
MINIMUM DILUTION

Case 1: Water Depth = 46m
Diffuser Length = 200m



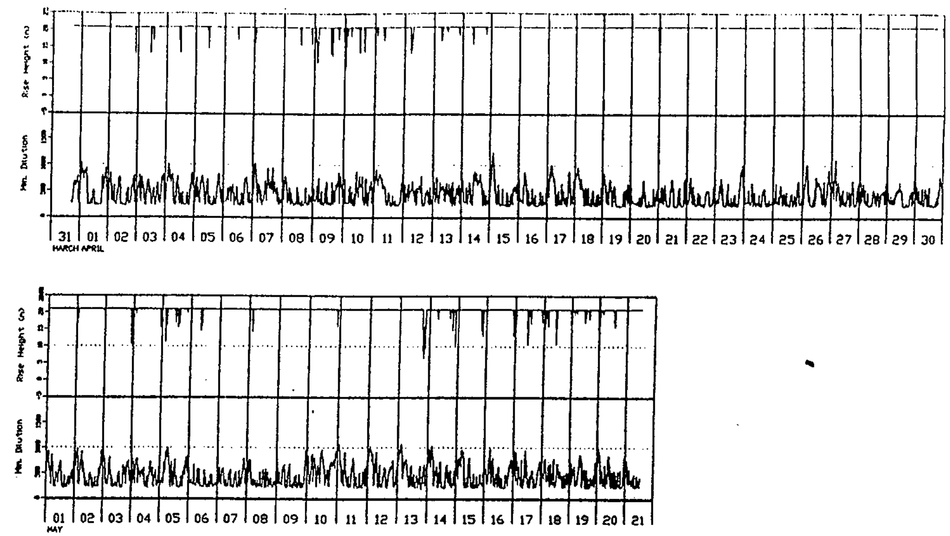
NEAR FIELD PLUME RISE HEIGHT AND
MINIMUM DILUTION

Case 1: Water Depth = 46m
Diffuser Length = 200m



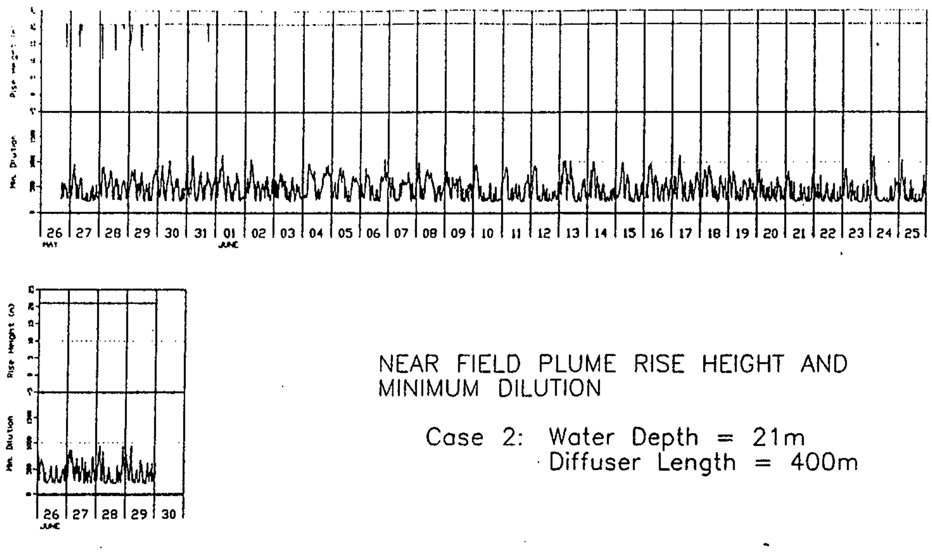
NEAR FIELD PLUME RISE HEIGHT AND MINIMUM DILUTION

Case 2: Water Depth = 21m
Diffuser Length = 400m



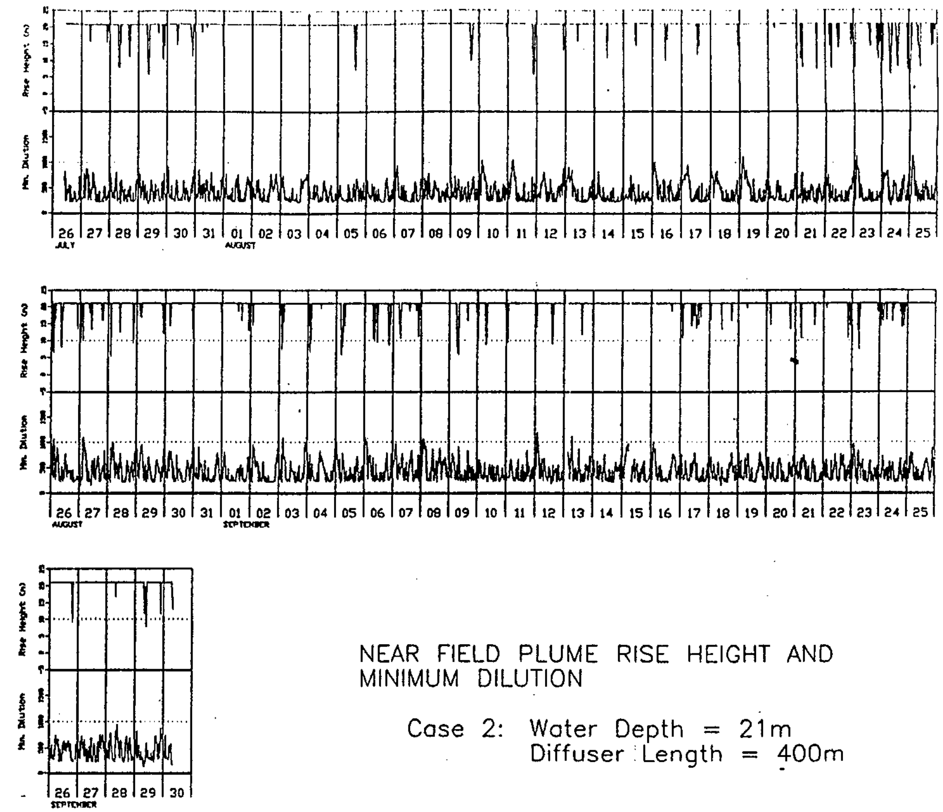
NEAR FIELD PLUME RISE HEIGHT AND MINIMUM DILUTION

Case 2: Water Depth = 21m
Diffuser Length = 400m



NEAR FIELD PLUME RISE HEIGHT AND MINIMUM DILUTION

Case 2: Water Depth = 21m
Diffuser Length = 400m



NEAR FIELD PLUME RISE HEIGHT AND MINIMUM DILUTION

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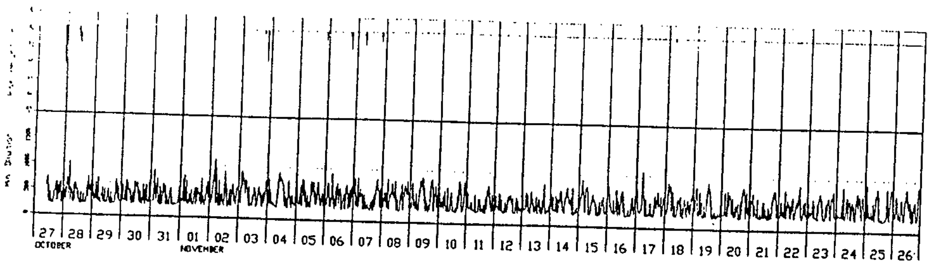
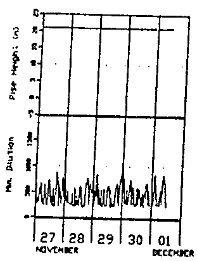
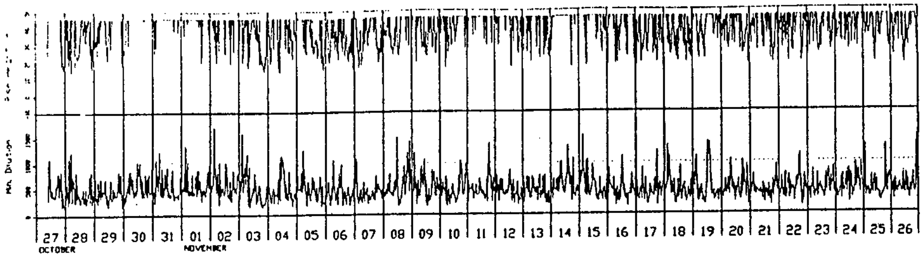
Diffuser Length = 400m

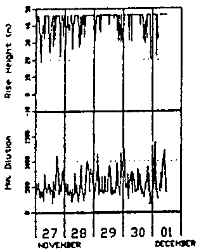




NEAR FIELD PLUME RISE HEIGHT AND
MINIMUM DILUTION

Case 2: Water Depth = 21m
Diffuser Length = 400m



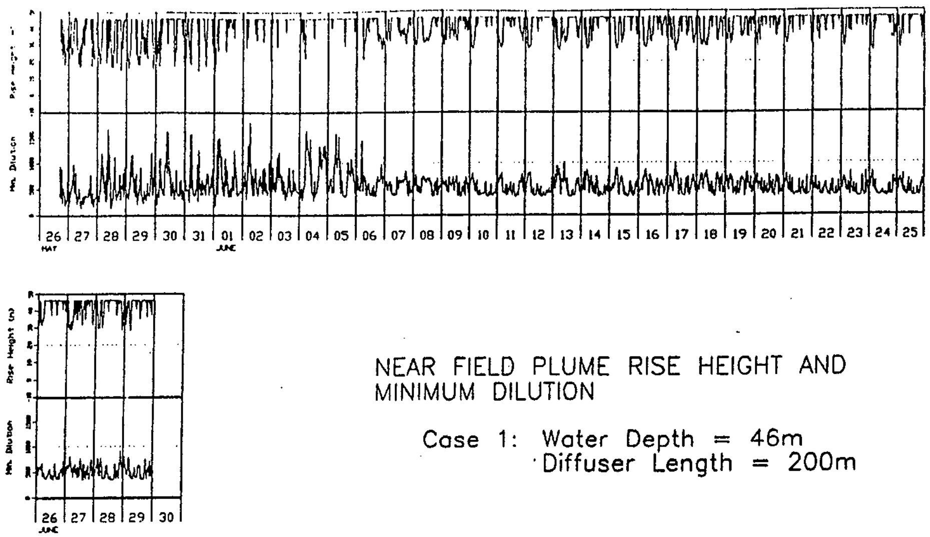


NEAR FIELD PLUME RISE HEIGHT AND MINIMUM DILUTION

Case 1: Water Depth = 46m
Diffuser Length = 200m

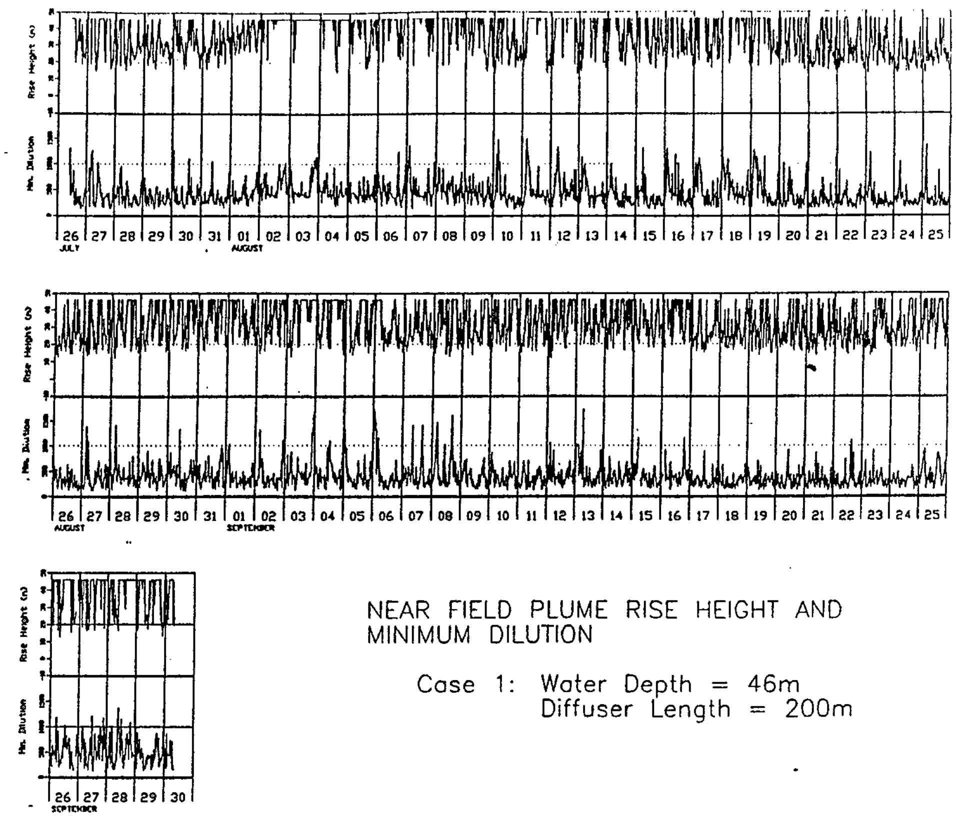
APPENDIX A-3

TIME SERIES DATA, CASE 2
PLUME RISE HEIGHT AND MINIMUM DILUTION



NEAR FIELD PLUME RISE HEIGHT AND MINIMUM DILUTION

Case 1: Water Depth = 46m
Diffuser Length = 200m



NEAR FIELD PLUME RISE HEIGHT AND MINIMUM DILUTION

Case 1: Water Depth = 46m
Diffuser Length = 200m

Appendix XII

Assessment of Far Field Water Quality: Fort Kamehameha Ocean Outfall Extension Oceanographic Study

ASSESSMENT OF FAR FIELD WATER QUALITY; FORT KAMEHAMEHA OCEAN OUTFALL EXTENSION OCEANOGRAPHIC STUDY

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I. EXECUTIVE SUMMARY

Planning is underway to extend the outfall for the Fort Kamehameha Wastewater Treatment Plant across the reef flat bordering the Pearl Harbor entrance channel, along the eastern channel wall out to an offshore depth of approximately 46 meters. Ambient conditions of water chemistry were evaluated in the "far field" area that will be potentially influenced by effluent discharge from the extended outfall. The far field area is centered at Pearl Harbor, and is bounded by the City and County of Honolulu deep ocean outfalls off Sand Island to the east and Honouliuli (Ewa Beach) to the west. Water samples were collected at three depths (surface, mid-depth, and bottom) at five locations (5, 15, 30, 50 and 80 mdepth contours) along five transects extending perpendicular to shore (75 samples per survey). Analysis of 13 water chemistry constituents included all parameters specified in DOH water quality standards. Three surveys were conducted (July and November 1996 and January 1997). The July sampling was conducted during a period of light tradewinds, and followed a prolonged period of dry weather; the November and January surveys were conducted during light Kona winds, and followed periods of heavy rainfall. Thus, the sampling scheme encompassed extremes in environmental conditions in terms of runoff from land, and different wind conditions.

Results of the sampling program reveal that salinity was lowest at nearly all of the surface and mid-depth stations during the November 1996 sampling compared to the other two dates. This trend was consistent along all five transects, and showed little longshore variation except in the Pearl Harbor Channel. The difference in salinity between the November sampling and the other two samples was greatest at the most inshore station (5 m contour), and decreased with water depth (moving offshore).This trend is consistent with input of low salinity water near the shoreline resulting from drainage following heavy rain.

The other distinct result with respect to salinity is the clear depression in values in surface samples in the Pearl Harbor Entrance Channel collected in November and January. At sampling stations out to the 30 m depth contour there was a distinct depression of surface salinity resulting from seaward flow of waters from Pearl Harbor

during periods of high rainfall. Beyond this distance from shore, there was little evidence of reduced salinity compared to the other sampling sites. During the July sampling there was little or no depression of salinity in the Pearl Harbor channel, indicating that during periods of dry weather there is little freshwater flow out of the Harbor.

Concentrations of Si and NO_3^- were elevated at all of the surface sampling stations at all sites in November compared to July and January. There was also a distinct peak in concentrations of Si, NO_3^- and PO_4^{3-} in the Pearl Harbor channel in November out to the 50 m depth contour. As these peaks were not present during the other two samplings, the elevated concentrations were apparently a result of drainage of rainfall and runoff out of Pearl Harbor. Concentrations of these constituents were somewhat elevated at sites to the east of Pearl Harbor relative to the west at all depth contours during the November sampling. This trend during November appears to be a result of light Kona winds which carried the surface plume eastward.

Total nitrogen (TN) does not occur in the same pattern of consistently increased concentrations in November relative to the other sampling dates. Several of the sampling sites reveal higher concentrations during the January sampling. The surface elevation in TN in the Pearl Harbor channel is only evident out to the 15 m depth contour. Surface turbidity at all sites was lower during the July survey than either the November or January periods. There is also a peak in turbidity in surface samples during November in the Pearl Harbor channel, indicating that water flowing out of Pearl Harbor following heavy rainfall is more turbid than coastal waters. However, there appears to be little difference in turbidity to the east and west of Pearl Harbor during any of the sampling dates. Plots of Chl a also show that concentrations were uniformly lowest during the July sampling compared to either the November or January dates

The most apparent feature of continuous profiles of salinity is steep gradient in the upper 5 m at many of the sampling sites. The surface gradients are most pronounced in the Pearl Harbor entrance channel, and reflect the surface layer of low salinity water flowing out of Pearl Harbor following heavy rain. Temperature throughout the water column was substantially cooler during the January sampling compared to the

November sampling. Below the surface layer (upper 5 m) there is little variation in temperature at the 15 and 30 m depth contours at any of the sites. Distinct thermoclines are apparent at the 50-70 m depth in profiles collected at the 80 m depth contour.

Comparison of results of the sampling program with Department of Health Water Quality standards reveals many exceedances of both geometric means limits and "not to exceed" specific limits. Samples collected from all transects exceeded some of these specific limits.

Overall results of the sampling program indicate that heavy rainfall had a substantial effect on water chemistry of the nearshore coastal ocean. Conversely, effects of discharge of effluent from the two large municipal deep water outfall was not clearly apparent in the water chemistry. Rainfall and subsequent discharge of runoff out of the Pearl Harbor estuary through the Pearl Harbor entrance channel appears to be the most important factor in affecting ambient water quality in the area that will be influenced by the Fort Kamehameha outfall extension.

II. INTRODUCTION

A. PROJECT DESCRIPTION

The Waste Water Treatment Plant (WWTP) at Fort Kamehameha was constructed in 1968 and treats domestic and industrial wastewater from the Pearl Harbor Naval Base, Hickam Air Force Base, and Hickam Village. The treatment plant is operated by the U.S. Navy. The effluent is presently discharged through a reinforced concrete pipe 549 meters (m) long, and 76 centimeters (cm) in diameter that runs along the east side of the Pearl Harbor entrance channel. The pipe terminates in a multi-port diffuser at the eastern edge of the entrance channel at a depth of 13.7 m. The receiving waters at the existing discharge site are regulated as a Class 2 inland estuary under current State of Hawaii Department of Health regulations.

The WWTP at Fort Kamehameha is presently being expanded to meet higher projected flows. The present flow is approximately 7.5 million gallons per day (MGD), while the projected average, maximum and peak flows are 13, 20 and 30 MGD, respectively. State regulations are very restrictive and stipulate that "no new industrial or sewage discharges will be permitted within estuaries". Thus, extending the outfall to discharge effluent into Class A "wet" open coastal waters will allow the projected increased flows to be discharged in compliance with existing regulatory requirements.

Present plans for the outfall extension involve placing the discharge pipe in a trench extending from the Treatment Plant across 1100 m of reef flat that extends along the eastern boundary of the Pearl Harbor entrance channel. At the edge of the reef flat the pipe will drop into the entrance channel and extend approximately 2440 m across the channel floor to a depth of 46 m. A 200 m long multiport diffuser will extend in a southeasterly direction along the 46 m depth contour.

As part of the environmental documentation required to support the proposed project, studies were conducted to assess the marine ecosystems in the vicinity of the proposed outfall and diffuser locations. A study completed in 1996 evaluated water chemistry in the area of the probable Zone of Mixing (ZOM) of the extended outfall, and qualitative descriptions of the marine biotic community structure in the area of the probable outfall routes (Marine Research Consultants 1996). These surveys provided the baseline of background conditions, as well as a basis for evaluation of possible environmental consequences of the proposed project within the ZOM. For preparation of the Environmental Impact Statement, further marine environmental investigations were warranted. Detailed assessment of biological communities across the reef flat and deeper areas of the potential outfall routes are presented in a separate report (Marine Research Consultants 1997). The present report is an evaluation of water quality beyond the potential boundaries of the ZOM in what is described as the "far field" region. This region is considered the area which may be influenced by discharge from proposed outfall, and is bounded by the existing Sand Island and Honouliuli Deep Ocean Sewage Outfalls. Presented below are the methods, results and discussion of the assessment of the far field water quality off the Fort Kamehameha Outfall extension.

III. METHODS

An important consideration of extending the Fort Kamehameha Outfall is the effect that discharge of effluent will have on receiving waters. In order to address this effect it is necessary to have a valid data base representing existing conditions of water chemistry in the area of the proposed extended outfall. With this goal in mind, a water chemistry sampling program was carried out over a 6-month period from July 1996 to January 1997. Sampling was conducted three times; on July 13, November 16, and January 21. Weather and sea conditions during the July sampling consisted of light tradewinds following a period of dry weather; both the November and January samplings occurred during calm to slightly Kona winds following periods of heavy rainfall. Thus, the three data sets bracket the extremes of dry and wet weather, and opposite wind directions.

Water samples were collected at the surface, at mid-depth and near that bottom at five depths along five transects that extended perpendicular from shore from the 5 meters (m) (15 foot) depth contour to the 80 m (250 foot) contour. The intermediate depths along the transects where samples were collected were 15 m (50 foot), 30 m (100 foot) and 50 m (150 foot). Transect 1 was located off Ewa Beach in the vicinity of the Honouliuli Deep Ocean Sewage Outfall; Transect 2 was located approximately midway between Ewa Beach and Pearl Harbor off the military rifle range; Transect 3 was located in the Pearl Harbor Entrance Channel; Transect 4 was located off the Reef Runway; and Transect 5 was located off Sand Island in the vicinity of the Deep Sewage Outfall. Figure 1 is a map of the south coast of Oahu showing the locations of the sampling transects.

Water sampling stations were located along each transect using a Global Positioning System (GPS) and fathometer. Water samples were collected from a boat using a 1.8 liter Niskin-type oceanographic sampling bottle. The bottle was lowered to the desired sampling depth with endcaps cocked in an open position so that water flowed freely through the bottle. At the desired depth a weighted messenger released from the surface tripped the endcaps closed, isolating a volume of water from the desired sampling depth. At all sampling stations, three water samples were collected; a surface

sample from within 10 centimeters (cm) of the air-sea interface, a mid-depth sample, and a deep sample within 50 cm of the ocean floor.

Water quality constituents that were evaluated include the 9 specific criteria designated for inland waters in Chapter 11-54, Section 05 (Pearl Harbor waters) of the Water Quality Standards, Department of Health, State of Hawaii. These criteria include: total nitrogen (TN), nitrate + nitrite nitrogen ($NO_3^- + NO_2^-$), ammonium (NH_4^+), total phosphorus (TP), chlorophyll a (Chl a), turbidity, salinity, pH and temperature. In addition, orthophosphate phosphorus (PO_4^{-3}), silica (Si), dissolved organic nitrogen (DON) and dissolved organic phosphorus (DOP) are also reported because these constituents can be indicators of biological activity and the degree of inputs from terrestrial sources.

Subsamples for nutrient analyses were immediately passed through sub-micron filters (GF-F) into 125-milliliter (ml) acid-washed, triple rinsed, polyethylene bottles and stored on ice until returned to the laboratory. Analyses for NH_4^+, PO_4^{3-}, NO_3^-, and Si were performed using a Technicon autoanalyzer according to standard methods for seawater analysis (Strickland and Parsons 1968, Grasshoff 1983). TN and TP were analyzed in a similar fashion on unfiltered samples following oxidative digestion. Dissolved organic nitrogen (DON) and dissolved organic phosphorus (DOP) were calculated as the difference between TN and dissolved inorganic N, and TP and dissolved inorganic P, respectively. The level of detection for the dissolved nutrients is 2.8 µg/L for TN, 5.6 µg/L for Si, 0.6 µg/L for TP, 0.31 µg/L for PO_4^{3-}, and 0.14 for NO_3^- and NH_4^+.

Water for other analyses was sub-sampled from 1-liter polyethylene bottles and kept chilled until analysis. Turbidity was determined on 60-ml subsamples fixed with $HgCl_2$ to terminate biological activity. Fixed samples were kept refrigerated until turbidity was measured on a Monitek Model 21 90-degree nephelometer, and reported in nephelometric turbidity units (ntu) (level of detection 0.01 ntu). Chl a was measured by filtering 300 ml of water through glass fiber filters; pigments on filters were extracted in 90% acetone in the dark at -5° C for 12-24 hours, and the fluorescence before and after acidification of the extract was measured with a Turner Designs fluorometer (level of detection 0.01 µg/L). Salinity was determined using an AGE Model 2100

laboratory salinometer with a precision of 0.0003 ‰. pH was determined using a field meter with a combination electrode with precision of 0.01 pH units.

Nutrient, turbidity, Chl a and salinity analyses were conducted by Marine Analytical Specialists (Laboratory Certification NO: HI-0009) of Honolulu, HI.

Continuous profiles of salinity and temperature were acquired using a Ocean Sensors Model 100 CTD,

IV. RESULTS

1. Patterns of Water Chemistry Constituents

Tables 1-3 show results of all water chemistry analyses for all samples collected during each of the three sampling events. Also shown in Tables 1-3 are the latitude and longitude and water depths at each of the sampling stations. Figures 2-46 are scatter plots that show concentrations of nine chemical constituents at each sampling station during each of the sampling events. Separate plots are shown for each sampling depth (surface, mid-depth and bottom) at each sampling site. The orientation of sampling sites in Figures 2-46 runs approximately from east to west (see Figure 1).

Several overall points can be made regarding the horizontal and vertical distribution of water chemistry constituents from the data sets as represented in Figures 2-46. First, salinity was lowest at nearly all of the surface and mid-depth stations during the November 1996 sampling compared to the other two dates. This trend was consistent along all five transects, and appears to show little longshore variation except in the Pearl Harbor Channel. The difference in salinity between the November sampling and the other two samples was greatest at the most inshore station (5 m contour), and decreased with water depth (e.g. moving offshore). This trend would be expected if the lower salinity is a result of input of low salinity water from drainage from land following heavy rain. At the shallowest sampling location (5 m), a gradient of salinity is evident in surface, mid-depth and bottom samples. At the 80 m station, the difference in salinity during November is evident in surface samples, but not in bottom samples.

It is somewhat surprising that July and January data reveal very similar salinities at nearly all stations. As stated above, the July sampling was conducted after a period of dry weather, while the January sampling was conducted after a period of heavy rain. It would be expected that the January results would be similar to November results with depressed salinity, at least in the surface samples.

The other distinct result with respect to salinity is the clear depression in values in surface samples on Transect 3 located in the Pearl Harbor Entrance Channel collected in November, and to a lesser extent in January. At locations out to the 30 m depth contour, there was a distinct depression of surface salinity resulting from seaward flow of waters from Pearl Harbor following periods of high rainfall. Beyond this distance from shore, there is little evidence of reduced salinity compared to the other sampling sites. During the July sampling, there was little or no depression of salinity in the Pearl Harbor channel, indicating that during periods of dry weather there is little freshwater flow out of the Harbor.

Plots of the dissolved nutrients Si (Figures 7-11), NO_3^- (Figures 12-16) show essentially a mirror image of the salinity plots. Concentrations of both of these constituents are elevated at all of the surface sampling stations at all sites in November compared to July and January. This pattern is also apparent in the mid-depth samples out to the 80 m depth contour. Samples collected near the bottom showed elevated levels of NO_3^- out to the 50 m depth contour at most of the sampling sites in November. At the 15 m depth contour, bottom samples showed a consistently large difference between samplings, with samples collected in November elevated by at nearly an order of magnitude over the other two sampling dates.

Considering surface samples, there was a distinct peak in concentrations of Si and NO_3^- in the Pearl Harbor channel (Site 3) in November out to the 50 m depth contour. As these peaks are not present during the other two samplings, the elevated concentrations are apparently a result of drainage of rainfall and runoff out of Pearl Harbor. Concentrations of these constituents are somewhat elevated at Sites 4 and 5 relative to Sites 1 and 2 at all depth contours during the November sampling. During tradewind weather, it has been observed that flow out of Pearl Harbor turns westward, with little effect to the east (Marine Research Consultants 1996). The opposite trend

during November appears to be a result of light Kona winds which carry the surface plume eastward.

The only deviation to the trend of higher concentrations of Si and NO_3^- in the November sampling is in bottom samples at the 80 m depth contour. In particular, concentrations of NO_3^- were elevated at Stations 1-3. These elevated concentrations may be a result of sewage effluent discharge from the Honouliuli outfall located near Station 1. However, if this is the case, it might be expected that concentrations would be elevated during all three of the samplings.

Plots of NH_4^+ (Figures 22-26) also reveal elevated concentrations at many of the sampling sites in November relative to the other two dates. However, the peak in concentrations in surface waters of Site 3 in the Pearl Harbor entrance channel is not as apparent as for NO_3^- or Si. At the 80 m depth contour, bottom samples at Sites 1-3 were substantially elevated in November, while concentrations of NO_3^- were elevated at the same locations in January. It appears that at these locations the same factors are not responsible for elevated NO_3^- and NH_4^+.

Plots of total nitrogen (TN) do not reveal the same pattern of consistently increased concentrations in November relative to the other sampling dates. Several of the sampling sites reveal higher concentrations during the January sampling. The surface elevation in TN at Site 3 in the Pearl Harbor channel is only evident out to the 15 m depth contour.

Plots of concentrations of PO_4^{3-} closely resemble plots of NO_3^- with elevated concentrations in most surface and mid-depth samples in November, and peaks in surface values at Site 3. It is also evident that concentrations of PO_4^{3-} in surface samples collected during the November sampling are higher to the east of Pearl Harbor than to the west, indicating lack of tradewind generated flow. During the July sampling, there is no indication of increased concentration of PO_4^{3-} in water in the Pearl Harbor channel. As with TN and NO_3^-, the pattern of TP does not closely resemble the inorganic form of phosphorus (PO_4^{3-}). Most sampling stations had higher concentrations of TP during the January sampling compared to November (Figures 32-36).

Plots of turbidity show that at all stations, surface turbidity was lower during the July survey than either the November or January periods (Figures 37-41). There is also a peak in turbidity in surface samples during November at Station 3, indicating that water flowing out of Pearl Harbor following heavy rainfall is more turbid than coastal waters. However, there appears to be little difference in turbidity to the east and west of Pearl Harbor during any of the sampling dates.

Plots of Chl a also show that concentrations were uniformly lowest during the July sampling compared to either the November or January dates (Figures 42-46). Surface samples at all depth contours showed consistently higher concentrations during the November sampling at Stations 1-3 to the west of Pearl Harbor compared to Stations 4-5 to the east of the Harbor. This result is in contrast to dissolved nutrients (NO_3^- and PO_4^{3-}) which had higher concentrations to the east of Pearl Harbor. This relationship suggests that uptake of nutrients by phytoplankton may have occurred in November at stations to the west of Pearl Harbor to a greater extent than to the east.

Overall results of the sampling program indicate that the effects of rainfall had a substantial effect on water chemistry than discharge of effluent from the two large municipal deep water outfall. Rainfall and subsequent discharge of runoff out of the Pearl Harbor estuary through the Pearl Harbor entrance channel appears to be the most important factor in affecting ambient water quality in the area that will be influenced by the Fort Kamehameha outfall extension.

2. CTD Profiles

Figures 47-54 show vertical profiles of salinity and temperature at each of the sampling stations acquired during the November and January samplings. Malfunction of the CTD prevented acquisition of profiles during the July sampling. Profiles are grouped in each Figure according to the depth contour where the cast was conducted.

The most apparent feature of the salinity profiles is the steep gradients in the upper 5 m of many of the plots. The surface gradients are most pronounced at Station T-3, and reflect the surface layer of low salinity water flowing out of the Pearl Harbor channel. As discussed above, the low salinity layer is likely a result of discharge of estuarine

water from inner Pearl Harbor. It is also apparent in Figures 47 and 51 that flow of freshwater out of Pearl Harbor was substantially greater in November than in January. Surface salinity at the surface at the 5 m contour was about 18‰ in November compared to 32.5‰ in January. While not as great as at Site 3, there are readily visible gradients of increasing salinity with depth at all of the other transect sites at depth contours of 5 to 30 m (Figure 47). During the January sampling, salinity gradients are substantially smaller at all sites, and are virtually nonexistent at Site 4. At the 50 and 80 m depth contours, gradients of salinity are evident to depths of about 20 m at Site 3 in November, but are do not occur in January (Figures 48 and 52).

Profiles of temperature reveal cooler surface layers at some sampling sites and warmer layers at other sites with no apparent pattern (Figures 49 and 53). Water temperature throughout the water column was substantially cooler during the January sampling compared to the November sampling. Below the surface layer (upper 5 m) there is little variation in temperature at the 15 and 30 m depth contours at any of the sites. Temperature profiles at the 50 and 80 m depth contours however show substantial subsurface gradients of temperature. Distinct thermoclines with gradients of about 2°C are evident at depths of 70-75 m at Transect sites 2 and 3 in November. Less distinct thermoclines are also evident in November at Transect sites 1, 4 and 5 (Figure 50). During January, the thermocline is evident at about 45 m at Transect site 1 and 60 m at Site 3 (Figure 54). No thermocline was evident in the cast at Site 4 to a depth of 70 m in January.

3. Compliance with DOH Criteria

State of Hawaii Department of Health (DOH) water quality standards specify specific criteria for geometric means and "not to exceed the given value more than 10% of the time and 2% of the time" for open coastal waters under "wet" conditions (Table 4).

Table 5 shows geometric means of the three samples at each sampling site. None of the geometric means of TP exceed either the wet or dry limits. All but one of the geometric means of TN exceeds the specific limits for wet conditions, while 34 geometric means exceed the wet limit. Twelve geometric means of NO_3^- exceed the wet limits, and 17 means of NO_3^- exceed the dry limits. Eleven geometric means of

NH_4^+ exceed the wet limit, and 51 means exceed the dry limit. Two geometric means of turbidity exceed the wet limit, and 18 exceed the dry limit. Ten geometric means of Chl a exceed the wet limit, and 52 exceed the dry limit. It is clear that there is a substantial difference in the degree of compliance between wet and dry conditions. It is also apparent that some chemical constituents, particularly TN, occur at concentrations that presently exceed the geometric mean limits on a regular basis.

With only three samples per site, the consideration of exceeding specific limits 10% or 2% of the time is not realistic. However, comparing values of water chemistry concentrations to the 10% and 2% limits provides some indication of the degree of compliance of the present conditions. During the November sampling, only five measurements (one NH_4^+ and four TN) exceeded the 10% criteria, while no measurements exceeded the 2% criteria. During the November sampling, which followed a prolonged period of heavy rain, 35 of the 75 samples exceeded the 10% standard for NO_3^-, 39 samples exceeded the standard for NH_4^+, 17 samples exceeded the standard for TN, 18 samples exceeded the standard for Chl a, and 5 samples for turbidity. During the January sampling, which also followed a period of rainfall, 2 samples exceeded the 10% standard for NO_3^-, 11 samples exceeded the standard for NH_4^+, 30 samples exceeded the standard for TN, and 5 samples exceeded the standard for turbidity. It appear clear that the amount of input to the coastal ocean as a function of runoff from land is very influential in affecting the degree of compliance of nearshore waters with DOH water quality standards.

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TABLE 1. Water chemistry measurements (in µg/L) from waters in the vicinity of Fort Kamehameha sewage outfall extension collected on July 13, 1996. Abbreviations as follows: Z= bottom depth; S=surface; M=mid; D=deep; BDL=below detection limit. For sampling locations, see Figure 1.

SITE	STA	GPS	Z (m)	SAMPLE #	PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	SI (µg/L)	DOP (µg/L)	DON (µg/L)	TP (µg/L)	TN (µg/L)	TU (n.t.u.)	SAL (ppt)	CHL a (µg/L)	TEMP (° C)	pH (rel)
TRANSECT 1 - EWA		21°16.77 N		1 S	2.79	1.26	1.54	80.34	16.73	110.51	19.53	113.26	0.05	34.632	0.06	26.5	8.20
	1	158° 01.57 W	80	2 M	2.48	0.70	0.70	52.53	17.34	106.87	19.84	108.22	0.08	34.628	0.07	26.5	8.21
				3 D	1.86	0.56	0.42	55.34	7.74	96.64	9.61	97.58	0.05	34.759	0.21	24.8	8.19
		21°16.97 N		4 S	2.48	0.14	1.12	49.72	11.46	94.82	13.95	96.04	0.06	34.604	0.06	26.7	8.21
	2	158° 01.65 W	50	5 M	2.17	BDL	0.98	53.93	10.22	102.80	12.40	103.74	0.07	34.596	0.07	26.6	8.21
				6 D	2.48	BDL	0.84	68.82	7.43	148.88	9.92	149.66	0.05	34.587	0.07	26.7	8.21
		21°17.07 N		7 S	2.48	0.28	1.68	53.09	7.74	126.47	10.23	128.38	0.07	34.579	0.07	26.7	8.21
	3	158° 01.69 W	30	8 M	1.86	BDL	0.98	49.16	8.67	92.30	10.54	93.24	0.05	34.595	0.06	26.7	8.21
				9 D	1.86	0.14	1.82	60.96	7.43	174.79	9.30	176.68	0.05	34.596	0.08	26.7	8.21
		21°17.43 N		10 S	2.48	0.56	2.24	51.69	9.91	112.33	12.40	115.08	0.06	34.598	0.07	26.7	8.21
	4	158° 01.68 W	15	11 M	3.72	0.84	1.26	60.11	21.06	157.43	24.80	159.46	0.06	34.588	0.07	26.7	8.21
				12 D	2.79	0.42	0.56	50.00	7.12	136.98	8.92	137.90	0.06	34.591	0.06	26.7	8.21
		21°17.91 N		13 S	2.48	0.28	1.12	60.11	11.15	152.95	13.64	154.28	0.17	34.326	0.22	26.5	8.17
	5	158° 01.75 W	5	14 M	2.17	0.42	0.70	50.28	9.29	122.13	11.47	123.20	0.14	34.541	0.15	26.5	8.19
				15 D	1.55	0.42	0.56	48.60	7.12	103.78	8.68	104.72	0.09	34.598	0.16	26.5	8.20
TRANSECT 2 - RIFLE RANGE		21°16.96 N		16 S	1.86	0.14	0.98	56.18	7.74	110.23	9.61	111.30	0.08	34.545	0.10	26.5	8.20
	6	157° 59.90 W	80	17 M	1.86	0.14	BDL	41.29	7.43	106.31	9.30	106.40	0.04	34.615	0.06	26.7	8.21
				18 D	1.86	0.14	0.56	57.87	7.12	94.26	8.99	94.92	0.07	34.803	0.18	24.8	8.19
		21°17.10 N		19 S	1.86	0.98	1.64	63.48	8.67	192.44	10.54	194.88	0.10	34.537	0.10	26.7	8.19
	7	157° 59.93 W	50	20 M	1.86	0.14	0.84	66.29	7.74	97.48	9.61	98.42	0.09	34.568	0.13	26.7	8.20
				21 D	2.17	0.42	1.26	55.06	7.12	97.48	9.30	99.12	0.05	34.605	0.08	26.7	8.20
		21°17.21 N		22 S	2.17	0.56	1.26	62.92	7.74	180.40	9.92	182.14	0.08	34.576	0.10	26.5	8.19
	8	157° 59.93 W	30	23 M	2.17	0.70	1.26	65.17	7.12	102.24	9.30	104.16	0.08	34.606	0.12	26.7	8.20
				24 D	2.48	0.42	2.94	79.21	8.98	147.48	11.47	150.78	0.07	34.613	0.12	26.7	8.20
		21°17.47 N		25 S	2.17	0.98	2.66	66.29	8.05	240.62	10.23	244.16	0.09	34.534	0.14	26.7	8.18
	9	157° 59.95 W	15	26 M	2.17	1.40	1.64	49.44	6.81	125.63	8.99	128.52	0.10	34.600	0.14	26.7	8.19
				27 D	2.17	1.96	2.66	54.49	6.81	126.75	8.99	131.32	0.12	34.577	0.15	26.6	8.18
		21°17.81 N		28 S	2.17	1.40	2.80	61.24	6.50	116.67	8.68	120.82	0.14	34.449	0.17	26.7	8.15
	10	157° 59.95 W	5	29 M	2.17	1.26	2.38	62.36,	6.81	110.37	8.99	113.96	0.17	34.446	0.16	26.6	8.15
				30 D	2.48	2.10	1.96	58.99	8.36	120.87	10.85	124.88	0.14	34.579	0.16	26.6	8.16

TABLE 1 (cont.)

SITE	STA	GPS	Z (m)	SAMPLE #	PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	SI (µg/L)	DOP (µg/L)	DON (µg/L)	TP (µg/L)	TN (µg/L)	TU (n.t.u.)	SAL (ppt)	CHL a (µg/L)	TEMP (° C)	pH (rel)
TRANSECT 3 - PEARL HARBOR		21°17.44 N		31 S	2.17	0.42	1.96	62.08	7.74	97.48	9.92	99.82	0.07	34.636	0.06	26.8	8.20
	11	157° 57.05 W	80	32 M	1.86	0.28	1.82	45.51	8.67	139.78	10.54	141.82	0.07	34.629	0.07	26.8	8.21
				33 D	3.72	6.16	1.54	90.73	6.81	105.33	10.54	112.98	0.06	34.945	0.14	26.7	8.16
		21°17.69 N		34 S	2.48	0.56	1.82	49.44	7.12	124.37	9.61	126.70	0.05	34.626	0.04	26.8	8.21
	12	157° 57.20 W	50	35 M	2.48	0.56	2.80	48.88	8.98	162.05	11.47	165.34	0.09	34.635	0.06	26.8	8.21
				36 D	2.79	1.12	1.68	48.88	7.43	149.16	10.23	151.90	0.06	34.695	0.17	26.2	8.20
		21°17.79 N		37 S	2.48	0.56	1.82	59.27	8.36	164.57	10.85	166.88	0.06	34.633	0.07	26.7	8.20
	13	157° 57.26 W	30	38 M	2.48	0.42	2.66	52.25	10.22	133.62	12.71	136.64	0.06	34.659	0.08	26.8	8.21
				39 D	2.17	1.12	2.66	49.16	8.98	112.47	11.16	116.20	0.06	34.625	0.15	26.5	8.19
		21°18.50 N		40 S	1.86	1.96	2.10	55.34	7.43	148.46	9.30	152.46	0.10	34.627	0.16	26.8	8.15
	14	157° 57.62 W	15	41 M	3.10	1.40	0.56	59.83	5.27	121.01	8.37	122.92	0.09	34.615	0.19	26.7	8.17
				42 D	2.48	1.12	0.84	55.90	5.88	164.15	8.37	166.04	0.12	34.646	0.21	26.6	8.17
		21°18.74 N		43 S	2.48	1.54	0.56	106.46	6.81	173.53	9.30	175.56	0.14	34.538	0.30	26.8	8.16
	15	157° 57.63 W	5	44 M	2.48	1.68	0.70	105.34	11.15	165.55	13.64	167.86	0.19	34.594	0.30	26.6	8.14
				45 D	3.10	1.82	2.10	96.63	6.81	165.55	9.92	169.40	0.22	34.633	0.29	26.5	8.15
TRANSECT 4 - REEF RUNWAY		21°17.40 N		46 S	2.48	0.28	0.28	59.27	7.43	183.62	9.92	184.10	0.05	34.687	0.06	27.0	8.20
	16	157° 56.12 W	80	47 M	2.17	0.42	0.14	59.55	7.43	206.31	9.61	206.78	0.05	34.692	0.07	26.9	8.21
				48 D	3.10	1.12	1.12	89.05	8.67	149.44	11.78	151.62	0.06	34.896	0.29	24.7	8.18
		21°17.51 N		49 S	2.48	0.14	0.28	57.02	6.81	127.03	9.30	127.40	0.06	34.695	0.07	27.0	8.21
	17	157° 56.10 W	50	50 M	2.48	0.28	1.40	58.43	8.05	138.94	10.54	140.56	0.05	34.711	0.06	26.9	8.21
				51 D	3.10	1.54	2.80	76.00	8.36	180.68	11.47	184.94	0.06	34.847	0.24	25.2	8.19
		21°17.62 N		52 S	2.79	0.28	0.84	60.67	7.12	136.70	9.92	137.76	0.05	34.713	BDL	26.9	8.21
	18	157° 56.09 W	30	53 M	2.79	0.14	0.56	83.43	8.36	116.67	11.16	117.32	0.05	34.719	0.08	26.9	8.21
				54 D	3.10	0.28	0.84	61.24	8.05	108.41	11.16	109.48	0.05	34.698	0.08	26.7	8.21
		21°17.88 N		55 S	2.79	0.56	0.70	65.73	6.81	110.93	9.61	112.14	0.07	34.665	0.10	26.8	8.21
	19	157° 56.05 W	15	56 M	2.79	0.70	1.12	151.41	7.43	143.84	10.23	145.60	0.06	34.701	0.09	26.7	8.21
				57 D	3.10	0.70	1.26	56.74	7.74	146.36	10.85	148.26	0.07	34.702	0.10	26.8	8.21
		21°18.01 N		58 S	4.96	9.80	1.26	83.99	5.58	137.40	10.54	148.40	0.11	34.676	0.07	26.8	8.15
	20	157° 56.05 W	5	59 M	4.65	9.94	1.96	71.07	4.96	110.37	9.61	122.22	0.10	34.685	0.07	26.8	8.14
				60 D	4.65	9.80	1.54	98.03	4.65	90.62	9.30	101.92	0.10	34.701	0.08	26.8	8.15
TRANSECT 5 - STP		21°17.01 N		61 S	4.34	0.70	1.40	78.93	7.43	115.97	11.78	118.02	0.06	34.736	0.05	26.7	8.20
	21	157° 54.85 W	80	62 M	2.48	0.42	0.98	104.49	6.81	114.57	9.30	115.92	0.06	34.721	0.09	26.8	8.21
				63 D	5.27	3.08	8.40	91.01	6.19	98.88	11.47	110.32	0.07	34.978	0.26	23.5	8.17
		21°17.09 N		64 S	3.10	0.56	1.26	58.15	6.50	108.13	9.61	109.90	0.06	34.757	0.08	26.9	8.21
	22	157° 54.71 W	50	65 M	2.79	0.56	2.10	122.19	9.91	153.93	12.71	156.52	0.07	34.704	0.07	26.8	8.21
				66 D	4.34	1.40	3.92	147.19	6.50	100.70	10.85	105.98	0.06	34.819	0.05	25.0	8.19
		21°17.16 N		67 S	2.79	0.56	1.26	61.24	6.19	99.16	8.99	100.94	0.04	34.735	0.24	26.8	8.21
	23	157° 54.69 W	30	68 M	2.79	0.42	0.98	53.65	6.19	115.69	8.99	117.04	0.06	34.723	0.06	26.8	8.21
				69 D	2.79	0.70	1.54	75.28	8.67	166.95	11.47	169.12	0.05	34.712	0.11	26.7	8.21
		21°17.43 N		70 S	2.48	0.84	0.98	75.56	6.81	161.63	9.30	163.38	0.08	34.723	0.12	26.8	8.20
	24	157° 54.40 W	15	71 M	3.72	1.68	1.68	64.89	7.12	132.64	10.85	135.94	0.09	34.697	0.13	26.7	8.20
				72 D	4.65	1.12	0.84	114.05	6.50	140.20	11.16	142.10	0.07	34.691	0.11	26.8	8.21
		21°17.70 N		73 S	2.79	0.84	1.40	92.14	6.50	136.00	9.30	138.18	0.15	34.708	0.25	26.9	8.19
	25	157° 54.14 W	5	74 M	2.17	0.56	1.12	66.29	6.19	107.15	8.37	108.78	0.16	34.695	0.22	26.9	8.19
				75 D	2.79	0.84	3.22	68.82	6.19	110.09	8.99	114.10	0.16	34 712	0.24	26.9	8.19

TABLE 2. Water chemistry measurements (in µg/L) from waters in the vicinity of Fort Kamehameha sewage outfall extension collected on November 16, 1996. Abbreviations as follows: Z= bottom depth; S=surface; M=mid; D=deep. For sampling locations, see Figure 1.

SITE	STA	GPS	Z (m)	SAMPLE #	PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	SI (µg/L)	DOP (µg/L)	DON (µg/L)	TP (µg/L)	TN (µg/L)	TU (n.t.u.)	SAL (ppt)	CHL a (µg/L)	TEMP (°C)	pH (rel)
TRANSECT 1 - EWA		21°16.77 N		1 S	2.48	11.90	1.82	121.07	8.05	103.78	10.54	117.46	0.18	33.440	0.64	26.3	8.17
	1	158° 01.57 W	80	2 M	2.48	4.34	1.82	64.89	8.36	95.24	10.85	101.36	0.10	34.398	0.26	26.3	8.17
				3 D	2.48	1.82	4.90	54.49	8.05	103.22	10.54	109.90	0.08	34.771	0.16	24.8	8.16
		21°16.97 N		4 S	2.48	14.98	1.12	130.90	8.98	108.69	11.47	124.74	0.20	33.148	0.65	26.3	8.18
	2	158° 01.65 W	50	5 M	2.48	5.32	2.24	65.17	7.74	101.26	10.23	108.78	0.11	34.289	0.34	26.3	8.17
				6 D	2.48	2.24	5.88	58.99	7.74	92.86	10.23	100.94	0.10	34.621	0.22	26.0	8.17
		21°17.07 N		7 S	2.79	15.40	1.96	131.74	7.74	101.96	10.54	119.28	0.22	33.242	0.68	26.3	8.18
	3	158° 01.69 W	30	8 M	2.48	5.18	2.80	69.10	7.43	92.86	9.92	100.80	0.15	34.147	0.37	26.5	8.18
				9 D	2.79	7.14	3.64	69.10	8.05	90.76	10.85	101.50	0.30	34.198	0.32	26.5	8.17
		21°17.43 N		10 S	3.10	22.26	2.66	174.72	7.43	116.39	10.54	141.26	0.33	32.831	0.84	26.2	8.18
	4	158° 01.68 W	15	11 M	3.10	20.02	3.78	153.09	7.43	107.85	10.54	131.60	0.24	33.062	0.82	26.2	8.17
				12 D	3.10	13.16	3.78	113.20	8.67	114.57	11.78	131.46	0.18	33.553	0.59	26.3	8.17
		21°17.91 N		13 S	4.96	41.44	5.46	224.16	6.81	108.83	11.78	155.68	0.46	32.623	0.73	25.9	8.12
	5	158° 01.75 W	5	14 M	4.96	40.88	6.02	225.28	7.12	114.15	12.09	161.00	0.49	32.669	0.71	26.0	8.11
				15 D	4.96	26.74	5.88	147.47	7.43	111.35	12.40	143.92	0.59	33.592	1.39	26.3	8.12
TRANSECT 2 - RIFLE RANGE		21°16.96 N		16 S	1.86	5.60	3.64	81.18	8.36	98.18	10.23	107.38	0.14	33.957	0.44	26.5	8.17
	6	157° 59.90 W	80	17 M	2.48	1.26	6.44	57.30	8.36	98.18	10.85	105.84	0.10	34.738	0.20	26.5	8.17
				18 D	2.48	2.24	5.46	55.62	8.36	96.22	10.85	103.88	0.10	34.812	0.15	24.2	8.17
		21°17.10 N		19 S	2.17	8.12	2.94	94.66	8.05	98.18	10.23	109.20	0.14	33.775	0.51	26.5	8.18
	7	157° 59.93 W	50	20 M	2.17	7.42	3.92	83.71	9.91	186.42	12.09	197.68	0.16	33.999	0.47	26.5	8.18
				21 D	2.17	1.96	6.86	65.17	9.60	154.91	11.78	163.66	0.09	34.586	0.31	26.2	8.18
		21°17.21 N		22 S	2.17	9.10	3.64	103.37	9.29	160.79	11.47	173.46	0.15	33.690	0.53	26.4	8.19
	8	157° 59.93 W	30	23 M	2.48	8.12	4.62	100.84	8.05	131.66	10.54	144.34	0.20	33.891	0.49	26.4	8.18
				24 D	1.86	0.56	4.20	53.93	8.98	116.53	10.85	121.24	0.08	34.549	0.25	26.5	8.19
		21°17.47 N		25 S	2.48	16.38	4.48	159.27	8.98	215.55	11.47	236.32	0.19	33.245	0.78	26.4	8.19
	9	157° 59.95 W	15	26 M	2.48	12.04	5.04	127.81	9.60	158.41	12.09	175.42	0.16	33.582	0.65	26.3	8.19
				27 D	2.79	10.78	6.02	112.64	8.36	167.23	11.16	183.96	0.17	33.864	0.52	26.4	8.18
		21°17.81 N		28 S	3.41	41.02	7.56	311.24	9.60	203.65	13.02	252.14	0.41	32.027	1.24	26.3	8.17
	10	157° 59.95 W	5	29 M	4.96	31.92	7.00	200.00	6.50	116.81	11.47	155.68	0.26	33.027	0.78	26.3	8.15
				30 D	4.34	24.08	5.60	143.54	6.50	104.48	10.85	134.12	0.21	33.579	0.62	26.5	8.15

TABLE 2 (cont.)

SITE	STA	GPS	Z (m)	SAMPLE #	PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	SI (µg/L)	DOP (µg/L)	DON (µg/L)	TP (µg/L)	TN (µg/L)	TU (n.t.u.)	SAL (ppt)	CHL a (µg/L)	TEMP (°C)	pH (rel)
TRANSECT 3 - PEARL HARBOR		21°17.44 N		31 S	2.79	12.60	5.74	113.20	8.36	101.12	11.16	119.42	0.19	33.645	0.42	26.5	8.17
	11	157° 57.05 W	80	32 M	2.48	6.44	5.32	68.54	8.05	96.50	10.54	108.22	0.11	34.279	0.30	26.2	8.18
				33 D	2.48	2.80	7.14	57.58	8.36	92.44	10.85	102.34	0.09	34.793	0.19	24.1	8.17
		21°17.69 N		34 S	4.96	33.46	8.68	210.39	6.81	108.13	11.78	150.22	0.24	33.089	0.23	26.5	8.17
	12	157° 57.20 W	50	35 M	4.03	16.94	7.00	100.56	6.50	101.64	10.54	125.44	0.17	33.707	0.32	26.1	8.17
				36 D	2.17	1.64	5.32	49.44	8.05	93.56	10.23	100.38	0.12	34.698	0.24	26.0	8.17
		21°17.79 N		37 S	7.13	80.22	15.54	504.50	8.05	163.17	15.19	258.86	0.82	30.394	1.13	26.3	8.15
	13	157° 57.26 W	30	38 M	6.82	47.32	10.08	255.06	5.58	127.03	12.40	184.38	0.34	32.803	0.29	26.2	8.14
				39 D	4.34	30.80	8.26	208.15	7.12	125.63	11.47	164.64	0.31	33.008	0.68	26.3	8.15
		21°18.50 N		40 S	8.68	240.66	12.32	1882.03	13.32	322.84	22.01	575.68	2.40	20.005	0.61	26.3	8.15
	14	157° 57.62 W	15	41 M	6.51	36.54	6.44	167.70	4.34	176.06	10.85	218.96	0.26	33.184	0.50	26.3	8.13
				42 D	3.72	10.08	4.48	82.58	5.88	175.64	9.61	190.12	0.13	34.378	0.30	26.2	8.15
		21°18.74 N		43 S	10.85	168.90	17.92	939.61	5.88	200.71	16.74	377.44	1.38	26.550	1.70	25.7	8.08
	15	157° 57.63 W	5	44 M	5.27	23.24	6.44	125.28	5.58	137.64	10.85	167.16	0.22	33.919	0.39	26.4	8.12
				45 D	3.41	5.74	7.70	101.69	7.12	127.87	10.54	141.26	0.24	34.599	0.34	26.2	8.15
TRANSECT 4 - REEF RUNWAY		21°17.40 N		46 S	3.41	14.00	2.24	113.20	6.81	136.28	10.23	152.46	0.18	33.705	0.35	26.4	8.17
	16	157° 56.12 W	80	47 M	2.79	5.32	1.96	69.10	7.43	121.15	10.23	128.38	0.09	34.433	0.26	26.3	8.17
				48 D	2.79	3.78	2.66	61.80	7.12	116.11	9.92	122.50	0.08	34.822	0.15	24.2	8.16
		21°17.51 N		49 S	4.96	28.28	5.04	206.16	6.19	138.38	11.16	171.64	0.25	33.166	0.28	26.4	8.17
	17	157° 56.10 W	50	50 M	3.10	6.72	3.92	76.97	6.81	139.78	9.92	150.36	0.13	34.461	0.25	26.5	8.17
				51 D	2.48	3.08	5.04	68.26	7.43	94.12	9.92	102.20	0.09	34.661	0.25	26.3	8.17
		21°17.62 N		52 S	5.58	36.12	7.00	238.77	6.19	104.34	11.78	147.42	0.33	32.980	0.28	26.3	8.17
	18	157° 56.09 W	30	53 M	3.41	13.16	2.80	113.48	6.81	94.40	10.23	110.32	0.20	33.787	0.37	26.5	8.18
				54 D	2.79	5.46	5.18	70.51	7.43	94.82	10.23	105.42	0.10	34.569	0.25	26.2	8.17
		21°17.88 N		55 S	7.75	59.64	8.54	304.50	4.34	113.03	12.09	181.16	0.43	32.566	0.24	26.3	8.11
	19	157° 56.05 W	15	56 M	3.41	14.98	2.66	125.00	7.12	97.06	10.54	114.66	0.26	33.720	0.38	26.3	8.17
				57 D	3.10	9.52	3.64	76.97	6.50	119.47	9.61	132.58	0.11	34.406	0.26	26.3	8.17
		21°18.01 N		58 S	7.44	68.80	7.14	279.50	3.10	141.04	10.54	206.92	0.48	32.660	0.19	26.3	8.08
	20	157° 56.05 W	5	59 M	7.44	57.12	6.16	268.26	3.10	136.56	10.54	199.78	0.34	32.735	0.19	26.2	8.10
				60 D	6.51	44.10	4.90	205.34	3.41	133.48	9.92	182.42	0.36	33.264	0.23	26.2	8.13
TRANSECT 5 - STP		21°17.01 N		61 S	2.17	7.84	1.96	124.44	8.05	125.21	10.23	134.96	0.24	34.044	0.27	26.5	8.17
	21	157° 54.85 W	80	62 M	2.17	2.38	3.22	79.21	8.36	171.85	10.54	177.38	0.24	34.597	0.25	26.2	8.17
				63 D	3.41	4.20	2.52	66.29	8.36	215.13	11.78	221.76	0.09	34.836	0.13	25.0	8.15
		21°17.09 N		64 S	2.48	8.54	2.66	105.62	7.74	117.93	10.23	129.08	0.22	34.019	0.26	26.5	8.17
	22	157° 54.71 W	50	65 M	1.86	1.12	1.54	60.39	8.67	163.73	10.54	166.32	0.11	34.529	0.31	26.5	8.18
				66 D	2.17	2.66	3.92	63.76	8.36	179.00	10.54	185.50	0.10	34.625	1.87	26.0	8.17
		21°17.16 N		67 S	3.41	19.04	3.08	148.88	7.12	125.63	10.54	147.70	0.25	33.587	0.32	26.6	8.18
	23	157° 54.69 W	30	68 M	1.86	3.08	2.10	73.31	7.74	118.21	9.61	123.34	0.12	34.463	0.27	26.6	8.18
				69 D	2.48	2.94	3.22	59.83	7.43	112.05	9.92	116.16	0.10	34.577	0.26	26.4	8.17
		21°17.43 N		70 S	6.82	52.64	7.70	280.06	5.27	144.12	12.09	204.40	0.32	32.728	0.20	26.6	8.14
	24	157° 54.40 W	15	71 M	3.10	12.60	3.36	110.67	7.12	103.64	10.23	119.56	0.14	33.873	0.31	26.4	8.18
				72 D	4.03	9.10	2.66	79.49	6.50	140.20	10.54	161.90	0.13	34.368	0.29	26.3	8.17
		21°17.70 N		73 S	8.06	71.12	11.06	423.04	5.27	142.30	13.33	224.42	0.61	31.884	0.30	26.7	8.12
	25	157° 54.14 W	5	74 M	7.13	50.12	8.26	283.15	5.58	153.37	12.71	211.68	0.39	32.880	0.17	26.5	8.13
				75 D	4.65	21.56	3.64	111.52	5.58	115.55	10.23	140.70	0.24	34.135	0.29	26.5	8.16

TABLE 3. Water chemistry measurements (in µg/L) from waters in the vicinity of Fort Kamehameha sewage outfall extension collected on January 21, 1997. Abbreviations as follows: Z= bottom depth; S=surface; M=mid; D=deep; BDL=below detection limit; ND=no data. For sampling locations, see Figure 1.

SITE	STA	GPS	Z (m)	SAMPLE #	PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	SI (µg/L)	DOP (µg/L)	DON (µg/L)	TP (µg/L)	TN (µg/L)	TU (n.t.u.)	SAL (ppt)	CHL a (µg/L)	TEMP (° C)	pH (rel)
TRANSECT 1 - EWA		21°16.77 N		1 S	2.48	0.70	2.24	179.21	9.91	155.61	12.40	158.48	0.09	34.460	0.17	23.9	8.19
	1	158° 01.57 W	80	2 M	2.48	0.28	0.56	45.22	10.53	142.16	13.02	142.94	0.08	34.890	0.11	23.8	8.20
				3 D	5.89	24.08	0.70	78.93	8.98	105.33	14.88	130.06	0.05	34.975	0.06	19.8	8.12
		21°16.97 N		4 S	2.17	0.84	3.92	60.39	11.77	167.51	13.95	172.20	0.11	34.644	0.11	24.0	8.20
	2	158° 01.65 W	50	5 M	1.86	0.98	3.08	48.31	11.77	146.36	13.64	150.36	0.13	34.858	0.12	23.8	8.20
				6 D	2.17	1.54	1.12	43.26	11.15	136.84	13.33	139.44	0.07	34.887	0.11	22.0	8.20
		21°17.07 N		7 S	2.17	0.42	5.88	71.91	12.70	143.42	14.88	149.66	0.11	34.595	0.15	23.8	8.19
	3	158° 01.69 W	30	8 M	2.79	0.84	11.90	71.07	13.32	121.99	16.12	134.68	0.11	34.731	0.15	23.7	8.20
				9 D	1.86	0.70	4.48	50.56	13.01	129.14	14.88	134.26	0.08	34.872	0.11	23.8	8.20
		21°17.43 N		10 S	2.17	1.68	0.84	115.73	13.32	145.24	15.50	147.70	0.34	34.231	0.16	23.3	8.18
	4	158° 01.68 W	15	11 M	2.17	1.40	6.16	85.67	12.70	156.17	14.88	163.66	0.24	34.485	0.17	23.7	8.19
				12 D	3.72	1.96	11.62	65.73	11.15	114.57	14.88	128.10	0.20	34.826	0.22	23.8	8.20
		21°17.91 N		13 S	3.10	1.68	2.24	102.81	12.39	137.40	15.50	141.26	0.49	34.411	0.30	23.5	8.17
	5	158° 01.75 W	5	14 M	3.41	2.24	4.06	103.93	13.01	157.99	16.43	164.22	0.43	34.422	0.31	23.5	8.17
				15 D	4.34	2.24	4.34	106.74	13.01	192.58	17.36	199.08	0.40	34.425	0.35	23.5	8.17
TRANSECT 2 - RIFLE RANGE		21°16.96 N		16 S	2.17	0.98	7.00	83.15	13.32	148.74	15.50	156.66	0.23	34.632	0.18	23.9	8.20
	6	157° 59.90 W	80	17 M	1.55	BDL	1.54	41.01	12.39	117.79	13.95	119.28	0.07	34.892	0.11	23.9	8.21
				18 D	3.72	12.74	2.24	57.87	10.53	131.66	14.26	146.58	0.08	34.956	0.12	23.9	8.16
		21°17.10 N		19 S	2.17	1.54	8.82	88.20	12.39	183.20	14.57	193.48	0.28	34.572	0.15	23.9	8.19
	7	157° 59.93 W	50	20 M	1.24	0.14	2.66	43.54	12.70	156.03	13.95	158.76	0.07	34.880	0.12	23.9	8.21
				21 D	1.86	2.10	2.10	46.31	12.39	152.39	14.26	156.52	0.08	34.895	0.18	23.9	8.20
		21°17.21 N		22 S	2.48	1.26	9.10	81.74	13.63	149.58	16.12	159.88	0.21	34.626	0.17	24.1	8.19
	8	157° 59.93 W	30	23 M	1.86	0.42	3.78	50.84	12.39	159.53	14.26	163.66	0.08	34.884	0.12	23.9	8.21
				24 D	1.86	1.40	2.24	54.78	11.77	128.58	13.64	132.16	0.09	34.894	0.14	23.8	8.21
		21°17.47 N		25 S	2.48	0.98	19.04	78.37	13.01	150.84	15.50	170.80	0.11	34.787	0.16	24.2	8.19
	9	157° 59.95 W	15	26 M	1.86	0.84	3.64	55.06	12.39	141.88	14.26	146.30	0.09	34.844	0.14	23.9	8.21
				27 D	1.55	0.42	2.94	43.82	12.39	121.57	13.95	124.88	0.10	34.888	0.13	23.9	8.21
		21°17.81 N		28 S	2.79	4.20	9.38	82.87	12.70	190.06	15.50	203.56	0.49	34.409	0.26	23.8	8.16
	10	157° 59.95 W	5	29 M	3.41	3.92	4.62	78.37	12.08	184.46	15.50	192.92	0.38	34.428	0.29	23.8	8.16
				30 D	2.48	2.38	3.22	53.93	12.70	147.48	15.19	153.02	0.23	34.710	0.49	23.8	8.20

TABLE 3 (cont.)

SITE	STA	GPS	Z (m)	SAMPLE #	PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	SI (µg/L)	DOP (µg/L)	DON (µg/L)	TP (µg/L)	TN (µg/L)	TU (n.t.u.)	SAL (ppt)	CHL a (µg/L)	TEMP (° C)	pH (rel)
TRANSECT 3 - PEARL HARBOR		21°17.44 N		31 S	3.41	5.18	3.36	111.80	12.39	163.87	15.81	172.34	0.21	34.471	0.21	24.1	8.18
	11	157° 57.05 W	80	32 M	1.24	0.56	2.38	41.29	12.39	116.81	13.64	119.70	0.06	34.874	0.13	24.1	8.21
				33 D	4.65	18.90	2.10	69.10	11.15	143.00	15.81	163.94	0.05	34.959	0.10	20.8	8.14
		21°17.69 N		34 S	2.17	1.68	2.66	69.94	13.01	133.46	15.19	137.76	0.11	34.777	0.15	24.0	8.19
	12	157° 57.20 W	50	35 M	1.55	0.70	1.96	42.70	12.39	114.99	13.95	117.60	0.05	34.871	0.10	24.0	8.21
				36 D	1.55	0.98	2.52	45.51	11.46	151.54	13.02	154.98	0.09	34.886	0.17	24.0	8.21
		21°17.79 N		37 S	2.17	2.24	3.08	63.76	12.70	155.61	14.88	160.88	0.20	34.679	0.16	24.1	8.19
	13	157° 57.26 W	30	38 M	1.24	0.42	1.54	43.26	11.77	157.01	13.02	158.90	0.10	34.860	0.10	23.9	8.21
				39 D	1.55	0.70	2.24	41.85	11.46	140.62	13.02	143.50	0.09	34.880	0.16	23.9	8.21
		21°18.50 N		40 S	5.58	6.58	8.68	158.15	13.63	175.08	19.22	190.26	0.70	33.068	0.27	23.6	8.11
	14	157° 57.62 W	15	41 M	4.34	3.64	2.52	107.02	9.60	219.89	13.95	225.96	0.42	34.351	0.32	23.7	8.18
				42 D	2.48	0.84	0.98	61.52	10.84	214.85	13.33	216.58	0.14	34.833	0.26	23.9	8.20
		21°18.74 N		43 S	6.51	8.12	5.88	186.52	11.77	253.09	18.29	266.98	0.70	33.094	0.28	23.6	8.12
	15	157° 57.63 W	5	44 M	5.27	8.12	3.50	161.24	10.22	228.16	15.50	239.68	0.36	34.217	0.47	23.5	8.15
				45 D	4.03	2.80	4.34	94.10	10.84	241.46	14.88	248.50	0.38	34.745	0.48	23.6	8.19
TRANSECT 4 - REEF RUNWAY		21°17.40 N		46 S	2.48	1.40	0.70	57.87	9.29	205.33	11.78	207.34	0.16	34.724	0.16	24.1	8.19
	16	157° 56.12 W	80	47 M	1.86	0.42	0.42	43.82	10.53	229.84	12.40	230.58	0.04	34.885	0.12	24.1	8.21
				48 D	2.79	4.90	0.70	54.21	9.91	164.57	12.71	170.10	0.06	34.894	0.16	23.5	8.19
		21°17.51 N		49 S	2.48	2.24	1.40	96.35	10.53	196.08	13.02	199.64	0.26	34.774	0.14	24.1	8.19
	17	157° 56.10 W	50	50 M	1.86	BDL	0.56	40.73	10.53	218.63	12.40	219.10	0.09	34.888	0.12	24.1	8.21
				51 D	1.86	0.42	0.84	49.72	10.22	209.95	12.09	211.12	0.07	34.875	0.16	24.1	8.21
		21°17.62 N		52 S	2.79	1.96	1.26	57.02	9.91	235.30	12.71	238.42	0.18	34.763	0.21	23.9	8.19
	18	157° 56.09 W	30	53 M	1.86	0.84	0.84	49.72	9.29	220.73	11.16	222.32	0.16	34.834	0.16	23.9	8.20
				54 D	1.55	0.42	1.12	46.63	11.15	220.31	12.71	221.76	0.07	34.884	0.16	23.9	8.21
		21°17.88 N		55 S	2.79	3.36	2.10	48.60	10.22	250.01	13.02	255.36	0.19	34.751	0.12	24.3	8.19
	19	157° 56.05 W	15	56 M	1.86	0.42	1.12	43.82	10.22	195.94	12.09	197.40	0.10	34.854	0.16	23.9	8.21
				57 D	1.86	0.98	1.12	60.11	10.22	190.76	12.09	192.78	0.08	34.869	0.22	23.9	8.21
		21°18.01 N		58 S	3.41	5.88	2.66	55.90	9.29	173.53	12.71	182.00	0.27	34.755	0.18	24.0	8.18
	20	157° 56.05 W	5	59 M	2.79	4.20	1.82	48.03	10.22	225.08	13.02	231.00	0.23	34.796	0.25	23.9	8.19
				60 D	2.79	4.20	1.96	44.94	10.53	172.41	13.33	178.50	0.25	34.787	0.28	23.9	8.19
TRANSECT 5 - STP		21°17.01 N		61 S	2.17	1.26	1.68	58.15	9.91	164.71	12.09	167.58	0.24	34.741	0.15	ND	8.20
	21	157° 54.85 W	80	62 M	1.86	0.98	2.66	44.36	10.22	155.89	12.09	159.46	0.13	34.855	0.17	ND	8.21
				63 D	1.86	1.26	2.80	42.70	10.53	173.39	12.40	177.38	0.07	34.866	0.16	ND	8.21
		21°17.09 N		64 S	2.48	2.10	3.50	90.45	10.53	160.51	13.02	166.04	0.27	34.631	0.20	ND	8.20
	22	157° 54.71 W	50	65 M	2.17	0.98	2.38	44.66	9.91	170.87	12.09	174.16	0.11	34.829	0.18	ND	8.21
				66 D	1.55	0.98	2.66	42.14	10.53	184.04	12.09	187.60	0.11	34.851	0.17	ND	8.20
		21°17.16 N		67 S	1.86	2.52	3.08	135.96	10.84	220.73	12.71	226.24	0.31	34.467	0.17	ND	8.19
	23	157° 54.69 W	30	68 M	2.17	1.68	1.82	52.81	10.84	251.55	13.02	254.94	0.22	34.697	0.20	ND	8.20
				69 D	1.86	0.84	3.22	39.89	10.53	189.92	12.40	193.90	0.10	34.848	0.15	ND	8.21
		21°17.43 N		70 S	2.17	2.94	3.92	56.18	10.84	191.18	13.02	197.96	0.31	34.641	0.25	ND	8.20
	24	157° 54.40 W	15	71 M	1.86	1.96	3.22	45.22	10.53	158.27	12.40	163.38	0.16	34.726	0.20	ND	8.21
				72 D	2.17	2.24	2.10	45.51	10.53	169.47	12.71	173.74	0.21	34.716	0.22	ND	8.20
		21°17.70 N		73 S	3.10	6.16	3.64	101.97	11.46	219.05	14.57	228.76	0.41	34.257	0.29	ND	8.17
	25	157° 54.14 W	5	74 M	3.41	4.62	2.94	69.10	12.08	198.32	15.50	205.80	0.40	34.489	0.46	ND	8.18
				75 D	4.96	4.62	3.08	68.82	9.29	171.15	14.26	178.78	0.78	34.488	0.50	ND	8.18

TABLE 5. Geometric means of water chemistry measurements (in µg/L) collected from five transect sites in the vicinity of Fort Kamehameha sewage outfall extension during surveys conducted on 3 dates; July 13 and November 16, 1996 and January 21, 1997 (N=2 for temperature at Transect 5). For calculation of geometric means, detection limits were used for sample data below the detectable limit. Abbreviations as follows: Z= bottom depth; S=surface; M=mid; D=deep. For sampling locations, see Figure 1.

SITE	STA	GPS	Z (m)	SAMPLE #	PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	Si (µg/L)	DOP (µg/L)	DON (µg/L)	TP (µg/L)	TN (µg/L)	TU (n.t.u.)	SAL (ppt)	CHL a (µg/L)	TEMP (°C)	pH (rel)
TRANSECT 1 - EWA	1	21°16.77 N	80	1 S	2.58	2.19	1.84	120.35	11.01	121.30	13.67	128.23	0.09	34.1733	0.19	25.5	8.18
		158° 01.57 W		2 M	2.48	0.95	0.89	53.62	11.52	113.10	14.10	116.17	0.09	34.6381	0.13	25.5	8.19
				3 D	3.01	2.91	1.13	61.97	8.24	101.66	11.47	111.73	0.06	34.8349	0.13	23.0	8.16
	2	21°16.97 N	50	4 S	2.37	1.21	1.70	73.25	10.66	119.96	13.07	127.30	0.11	34.1248	0.16	25.6	8.20
		158° 01.65 W		5 M	2.16	0.90	1.89	55.38	9.77	115.07	12.01	119.27	0.10	34.5802	0.14	25.5	8.19
				6 D	2.37	0.78	1.77	56.00	8.63	123.68	11.06	128.19	0.07	34.6981	0.12	24.8	8.19
	3	21°17.07 N	30	7 S	2.47	1.22	2.69	79.53	9.13	122.75	11.71	131.84	0.12	34.1327	0.20	25.6	8.19
		158° 01.69 W		8 M	2.34	0.85	3.20	62.27	9.50	101.50	11.90	108.17	0.09	34.4901	0.15	25.6	8.19
				9 D	2.13	0.69	3.10	59.72	9.20	127.01	11.45	134.03	0.11	34.5542	0.14	25.6	8.19
	4	21°17.43 N	15	10 S	2.56	2.76	1.71	101.48	9.94	123.83	12.65	133.91	0.19	33.8780	0.21	25.4	8.19
		158° 01.68 W		11 M	2.92	2.87	3.08	92.38	12.57	138.41	15.73	150.87	0.15	34.0378	0.22	25.5	8.19
				12 D	3.18	2.21	2.91	71.92	8.83	121.60	12.03	132.42	0.13	34.3188	0.20	25.6	8.19
	5	21°17.91 N	5	13 S	3.37	2.69	2.39	111.48	9.80	131.75	13.55	150.26	0.34	33.7765	0.37	25.3	8.15
		158° 01.75 W		14 M	3.32	3.38	2.58	105.59	9.51	130.11	13.16	148.24	0.31	33.8664	0.32	25.3	8.16
				15 D	3.22	2.93	2.43	91.46	8.83	130.56	12.32	144.23	0.28	34.2022	0.42	25.4	8.16
TRANSECT 2 - RIFLE RANGE	6	21°16.96 N	80	16 S	1.96	0.92	2.92	72.38	9.52	117.20	11.51	123.25	0.14	34.3767	0.20	25.6	8.19
		157° 59.90 W		17 M	1.93	0.29	1.12	45.95	9.17	107.13	11.21	110.34	0.07	34.7481	0.11	25.7	8.20
				18 D	2.58	1.59	1.90	57.11	8.56	106.09	11.16	113.06	0.08	34.8569	0.15	24.3	8.17
	7	21°17.10 N	50	19 S	2.06	2.31	3.42	80.93	9.53	151.27	11.62	160.28	0.16	34.2927	0.20	25.7	8.19
		157° 59.93 W		20 M	1.71	0.53	2.06	62.28	9.91	141.54	11.75	145.63	0.10	34.4804	0.19	25.7	8.20
				21 D	2.06	1.20	2.63	55.76	9.46	132.02	11.60	136.42	0.07	34.6950	0.16	25.6	8.19
	8	21°17.21 N	30	22 S	2.27	1.86	3.47	81.01	9.93	163.10	12.24	171.58	0.14	34.2946	0.21	25.6	8.19
		157° 59.93 W		23 M	2.16	1.34	2.80	69.39	8.92	129.01	11.18	135.00	0.11	34.4578	0.19	25.6	8.20
				24 D	2.05	0.69	3.02	61.62	9.83	130.25	11.93	134.18	0.08	34.6850	0.16	25.6	8.20
	9	21°17.47 N	15	25 S	2.37	2.51	6.10	93.88	9.80	198.52	12.21	214.40	0.12	34.1819	0.26	25.7	8.19
		157° 59.95 W		26 M	2.16	2.42	3.05	70.33	9.32	141.34	11.57	148.86	0.11	34.3376	0.23	25.6	8.19
				27 D	2.11	2.07	3.61	64.55	8.90	137.10	11.19	144.49	0.13	34.4403	0.21	25.6	8.19
	10	21°17.81 N	5	28 S	2.74	6.22	5.83	116.45	9.26	165.29	12.05	183.72	0.30	33.6090	0.38	25.6	8.16
		157° 59.95 W		29 M	3.32	5.40	4.25	99.24	8.12	133.48	11.69	150.70	0.26	33.9604	0.33	25.5	8.15
				30 D	2.99	4.94	3.28	77.01	8.84	123.04	12.14	136.85	0.19	34.2856	0.36	25.6	8.17

TABLE 4. Specific Criteria for Class A Dry Open Coastal Waters based on Hawaii Administrative Rules, Title 11, Department of Health, Chapter 54, Water Quality Standards which apply to Receiving Water Limitations.

Parameter	Geometric mean not to exceed the given value	Not to exceed the given value more than 10% of the time	Not to exceed the given value more than 2% of the time
Total Nitrogen (µg N/L)	110.00	180.00	250.00
Ammonia Nitrogen (µg NH4-N/L)	2.00	5.00	9.00
Nitrate+Nitrite Nitrogen (µg [NO3+NO2]-N/L)	3.50	10.00	20.00
Total Phosphorus (µg P/L)	16.00	30.00	45.00
Chlorophyll a (µg/L)	0.15	0.50	1.00
Turbidity (NTU)	0.20	0.50	1.00

pH units - shall not deviate more than 0.5 units from a value of 8.1.

Temperature - shall no vary more than 1 deg.C from "ambient conditions".

Salinity - shall not vary more than 10% from natural or seasonal changes considering input and oceanographic factors.

Dissolved oxygen - not less than 75% saturation.

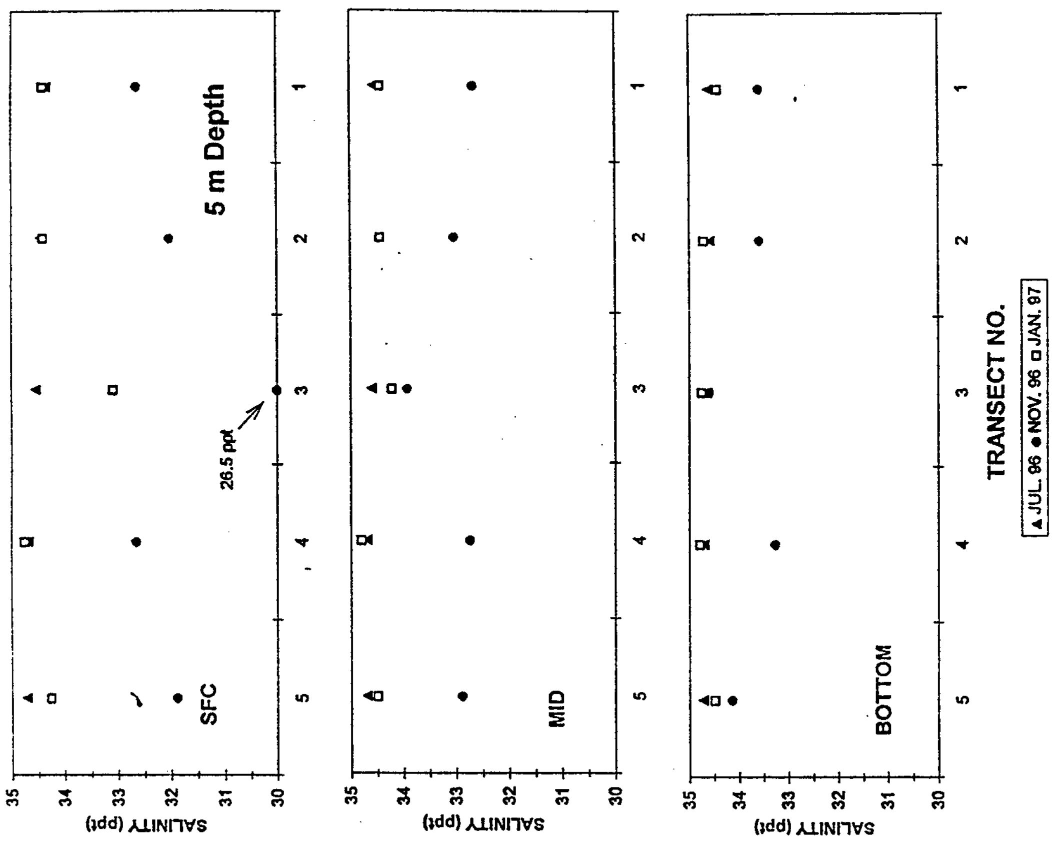


FIGURE 2. Scatter plots showing measurements of salinity in samples collected at the 5m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

TABLE 5 (cont.)

SITE	STA	GPS	Z (m)	SAMPLE #	PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	SI (µg/L)	DOP (µg/L)	DON (µg/L)	TP (µg/L)	TN (µg/L)	TU (n.t.u.)	SAL (ppt)	CHL a (µg/L)	TEMP (°C)	pH (rel)
TRANSECT 3 - PEARL HARBOR		21°17.44 N		31 S	2.74	3.02	3.36	92.27	9.29	117.33	12.05	127.12	0.14	34.2479	0.17	25.8	8.19
	11	157° 57.05 W	80	32 M	1.79	1.00	2.85	50.50	9.53	116.36	11.49	122.47	0.08	34.5931	0.14	25.7	8.20
				33 D	3.50	6.88	2.85	71.21	8.60	111.66	12.18	123.76	0.06	34.8989	0.14	23.7	8.15
		21°17.69 N		34 S	2.99	3.16	3.48	89.94	8.58	121.53	11.98	137.89	0.11	34.1554	0.11	25.7	8.19
	12	157° 57.20 W	50	35 M	2.49	1.88	3.37	59.43	8.98	123.69	11.80	134.61	0.09	34.4006	0.13	25.6	8.19
				36 D	2.11	1.19	2.82	47.81	8.82	128.36	11.09	133.20	0.09	34.7596	0.19	25.4	8.19
		21°17.79 N		37 S	3.37	4.65	4.43	124.00	9.49	161.07	13.49	190.83	0.21	33.1728	0.23	25.7	8.18
	13	157° 57.26 W	30	38 M	2.76	2.03	3.46	83.23	8.75	138.64	12.71	158.78	0.13	34.0946	0.13	25.6	8.19
				39 D	2.44	2.89	3.66	75.38	9.02	125.72	11.86	140.02	0.12	34.1608	0.25	25.5	8.19
		21°18.50 N		40 S	4.48	14.69	6.08	254.43	11.05	203.21	15.79	255.60	0.55	28.4001	0.30	25.5	8.14
	14	157° 57.62 W	15	41 M	4.44	6.71	2.09	102.40	6.03	187.33	10.82	182.53	0.21	34.0443	0.31	25.5	8.16
				42 D	2.84	2.12	1.54	65.73	7.21	183.65	10.24	189.80	0.13	34.6185	0.25	25.5	8.17
		21°18.74 N		43 S	5.60	12.57	3.89	265.23	7.79	206.57	14.17	260.57	0.61	31.1916	0.62	25.3	8.12
	15	157° 57.63 W	5	44 M	4.10	6.82	2.61	128.62	8.60	173.19	13.19	188.76	0.25	34.2422	0.38	25.5	8.14
				45 D	3.49	3.08	4.12	97.42	8.07	172.26	11.59	181.17	0.27	34.6589	0.37	25.4	8.16
TRANSECT 4 - REEF RUNWAY		21°17.40 N		46 S	2.76	1.76	0.76	72.95	7.78	172.56	10.61	179.87	0.11	34.3687	0.15	25.8	8.19
	16	157° 56.12 W	80	47 M	2.24	0.98	0.49	56.50	8.35	179.10	10.68	182.93	0.06	34.6695	0.13	25.7	8.20
				48 D	2.89	2.75	1.28	66.82	8.49	141.87	11.41	146.73	0.07	34.8706	0.19	24.1	8.18
		21°17.51 N		49 S	3.12	2.07	1.25	104.24	7.63	151.06	11.06	163.44	0.16	34.2036	0.14	25.8	8.19
	17	157° 56.10 W	50	50 M	2.43	0.64	1.45	56.79	8.33	161.93	10.80	166.68	0.08	34.6862	0.12	25.8	8.20
				51 D	2.43	1.26	2.28	63.37	8.60	152.84	11.12	158.61	0.07	34.7942	0.21	25.2	8.19
		21°17.62 N		52 S	3.52	2.71	1.95	93.83	7.59	149.72	11.41	169.18	0.14	34.1418	0.08	25.7	8.19
	18	157° 56.09 W	30	53 M	2.61	1.16	1.10	77.79	8.09	134.46	10.84	142.23	0.12	34.4435	0.17	25.7	8.20
				54 D	2.38	0.86	1.70	58.61	8.74	131.32	11.32	136.79	0.07	34.7235	0.15	25.6	8.20
		21°17.88 N		55 S	3.92	4.82	2.32	99.08	6.71	146.35	11.48	173.11	0.18	33.9788	0.14	25.8	8.17
	19	157° 56.05 W	15	56 M	2.61	1.64	1.49	93.95	8.15	139.86	10.92	148.81	0.12	34.4213	0.18	25.6	8.20
				57 D	2.61	1.87	1.73	64.03	8.01	149.42	10.80	155.90	0.09	34.6585	0.18	25.6	8.19
		21°18.01 N		58 S	6.01	15.02	2.88	109.48	5.43	149.82	11.22	177.46	0.24	34.0163	0.14	25.7	8.14
	20	157° 56.05 W	5	59 M	4.59	13.36	2.80	97.11	5.39	150.26	10.97	178.01	0.20	34.0587	0.15	25.6	8.15
				60 D	4.39	12.20	2.45	96.72	5.50	127.76	10.71	149.16	0.21	34.2435	0.17	25.6	8.16
TRANSECT 5 - STP		21°17.01 N		61 S	2.73	1.91	1.66	82.97	8.40	133.73	11.34	138.72	0.15	34.5054	0.13	26.6	8.19
	21	157° 54.85 W	80	62 M	2.16	0.99	2.03	71.62	8.35	145.33	10.58	148.56	0.12	34.7242	0.16	26.5	8.19
				63 D	3.22	2.64	3.90	63.63	8.17	154.51	11.88	163.11	0.08	34.8933	0.18	24.2	8.18
		21°17.09 N		64 S	2.67	2.16	2.27	82.20	8.09	126.97	10.86	133.05	0.15	34.4675	0.16	26.7	8.19
	22	157° 54.71 W	50	65 M	2.24	0.85	1.97	69.08	9.48	162.69	11.74	165.51	0.09	34.6871	0.15	26.6	8.20
				66 D	2.44	1.64	3.44	73.40	8.30	149.14	11.14	154.50	0.09	34.7649	0.25	25.5	8.19
		21°17.16 N		67 S	2.61	3.00	2.29	107.42	7.82	140.10	10.64	149.97	0.15	34.2595	0.23	26.7	8.19
	23	157° 54.69 W	30	68 M	2.24	1.30	1.55	59.22	8.04	150.96	10.40	154.39	0.12	34.6275	0.15	26.7	8.19
				69 D	2.34	1.20	2.52	56.43	8.79	152.59	11.22	157.07	0.08	34.7122	0.16	26.5	8.19
		21°17.43 N		70 S	3.32	6.07	3.09	105.94	7.30	164.53	11.35	187.68	0.20	34.0180	0.18	26.7	8.18
	24	157° 54.40 W	15	71 M	2.78	3.46	2.63	68.74	8.12	129.58	11.12	138.48	0.13	34.4297	0.20	26.5	8.20
				72 D	3.44	2.84	1.67	74.44	7.64	149.35	11.43	155.36	0.12	34.5913	0.19	26.5	8.19
		21°17.70 N		73 S	4.12	7.17	3.83	158.40	7.32	161.84	12.18	192.14	0.32	33.5931	0.28	26.8	8.16
	25	157° 54.14 W	5	74 M	3.75	5.06	3.01	109.06	7.47	148.26	11.81	167.97	0.29	34.0116	0.26	26.7	8.17
				75 D	4.01	4.37	3.30	80.83	6.85	129.61	10.95	142.11	0.31	34.4442	0.33	26.7	8.18

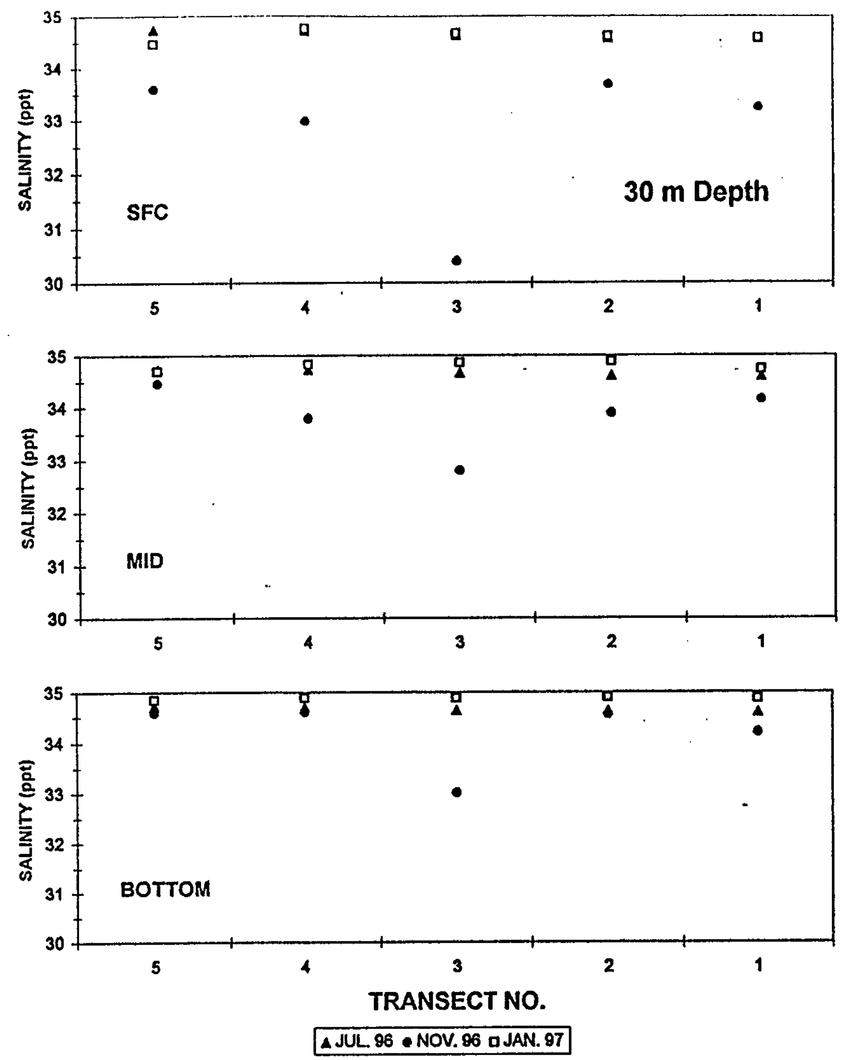


FIGURE 4. Scatter plots showing measurements of salinity in samples collected at the 30m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

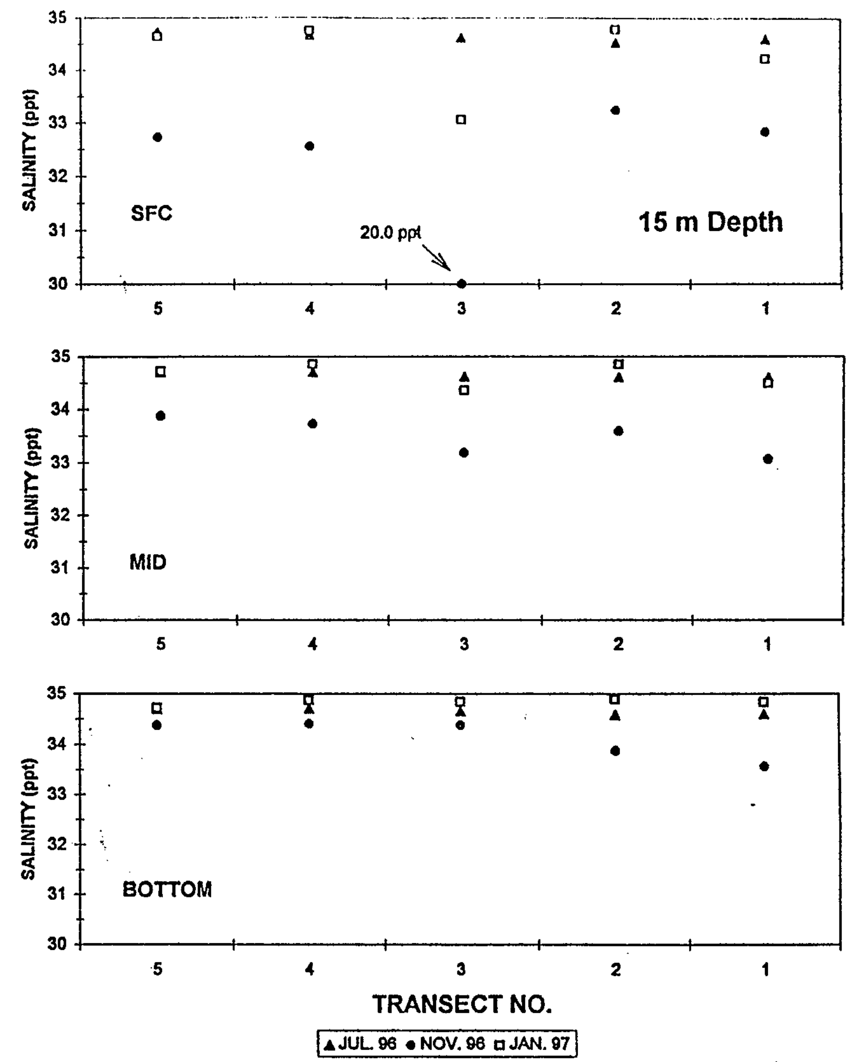


FIGURE 3. Scatter plots showing measurements of salinity in samples collected at the 15m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

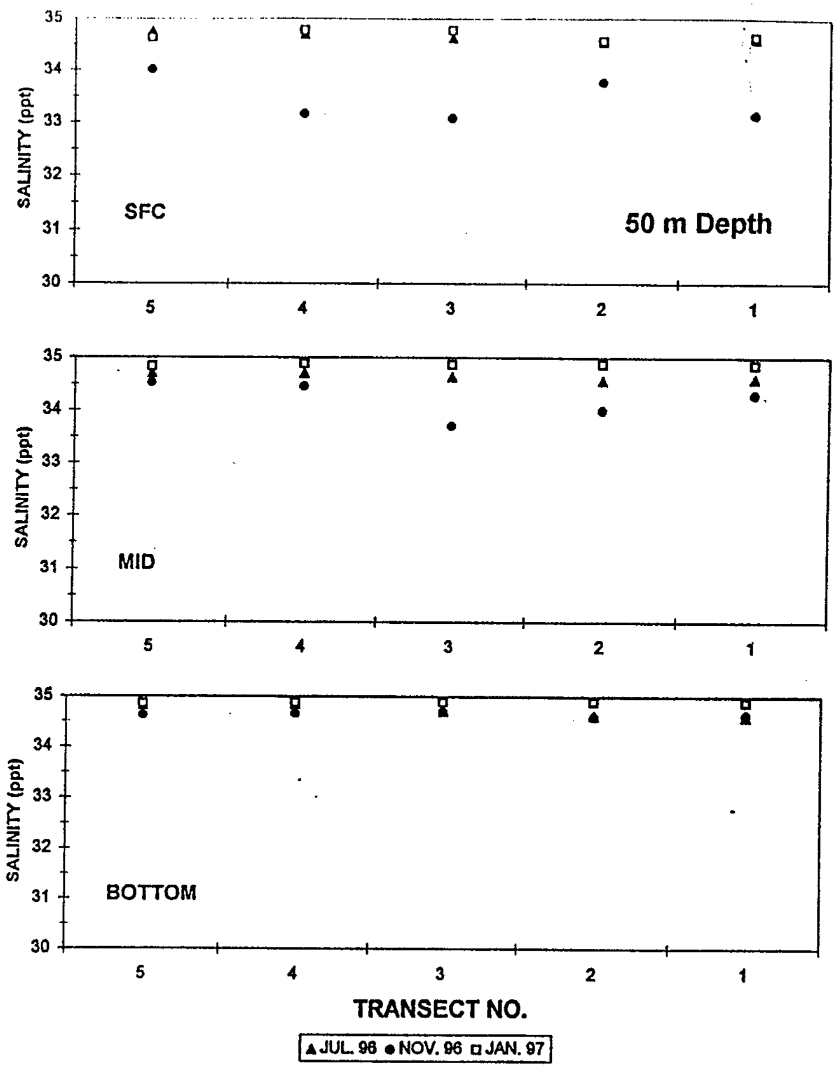


FIGURE 5. Scatter plots showing measurements of salinity in samples collected at the 50m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

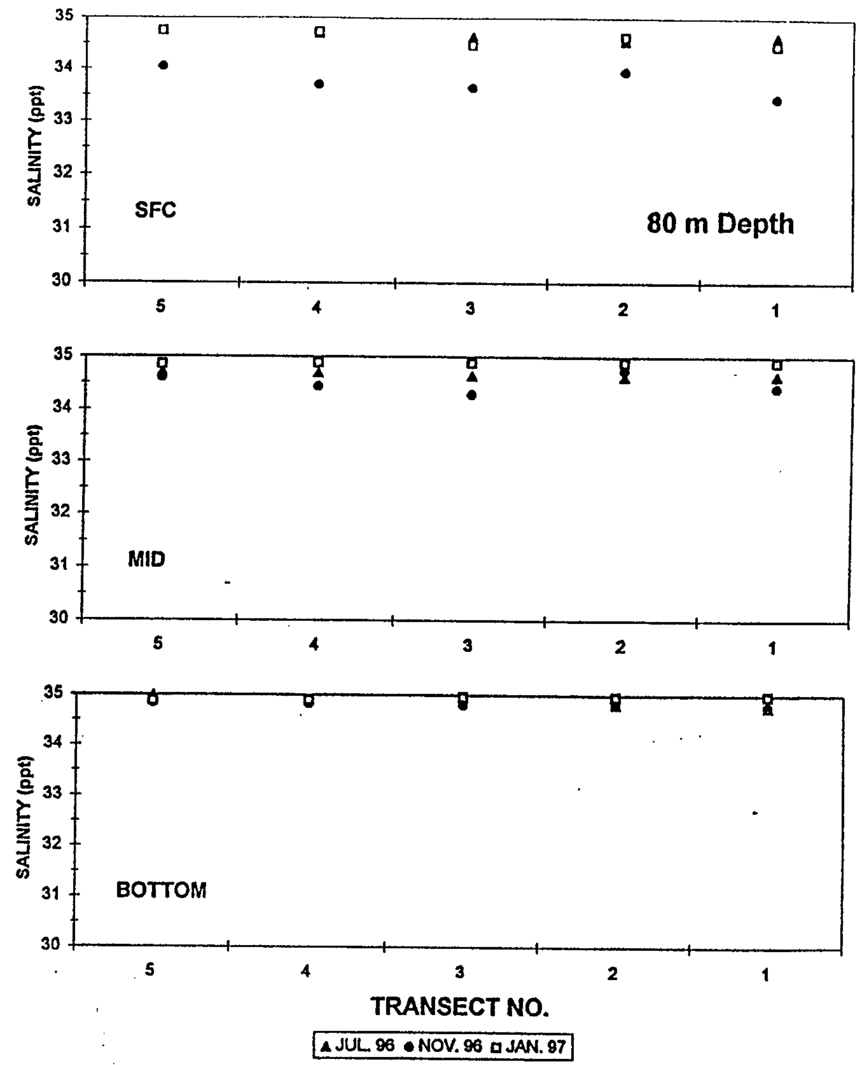


FIGURE 6. Scatter plots showing measurements of salinity in samples collected at the 80m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

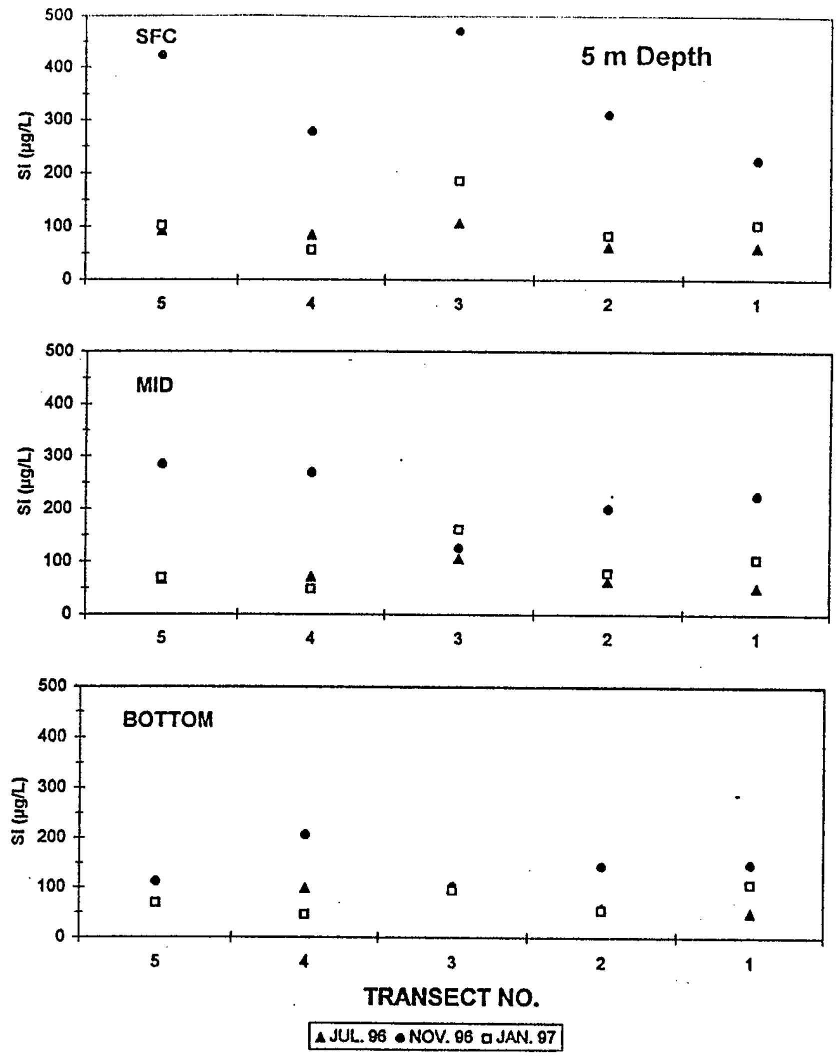


FIGURE 7. Scatter plots showing measurements of silicate in samples collected at the 5m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

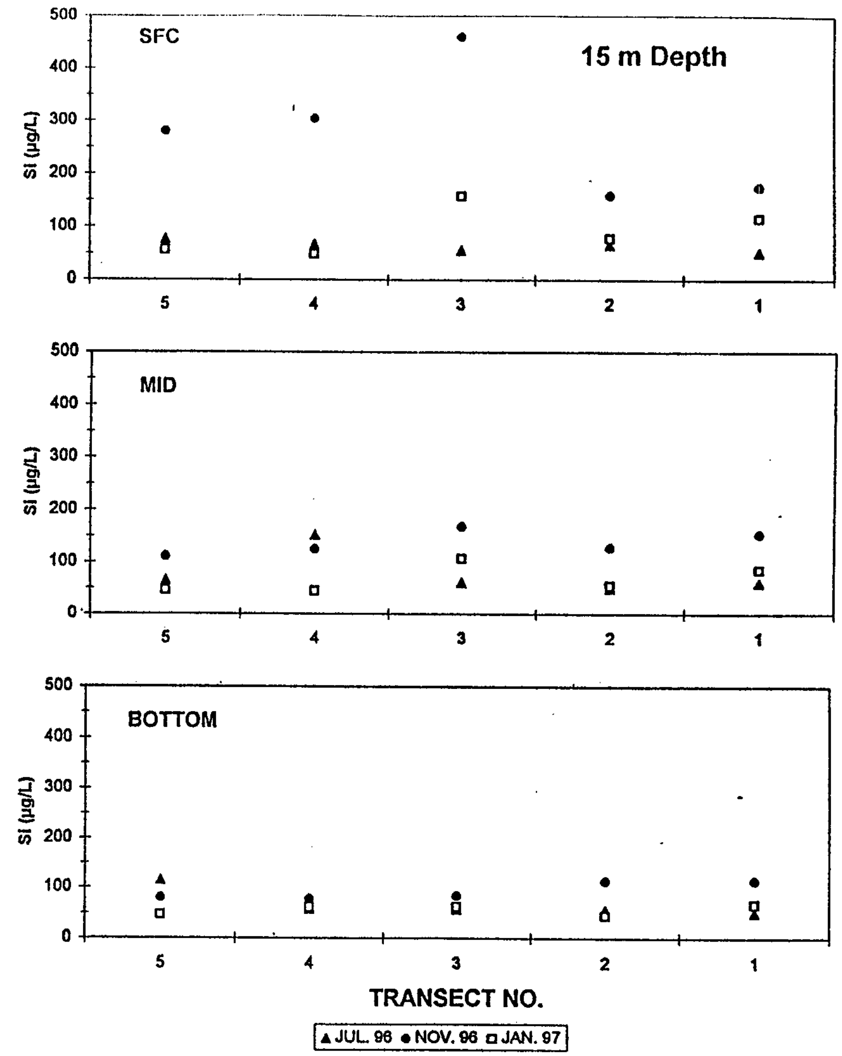


FIGURE 8. Scatter plots showing measurements of silicate in samples collected at the 15m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

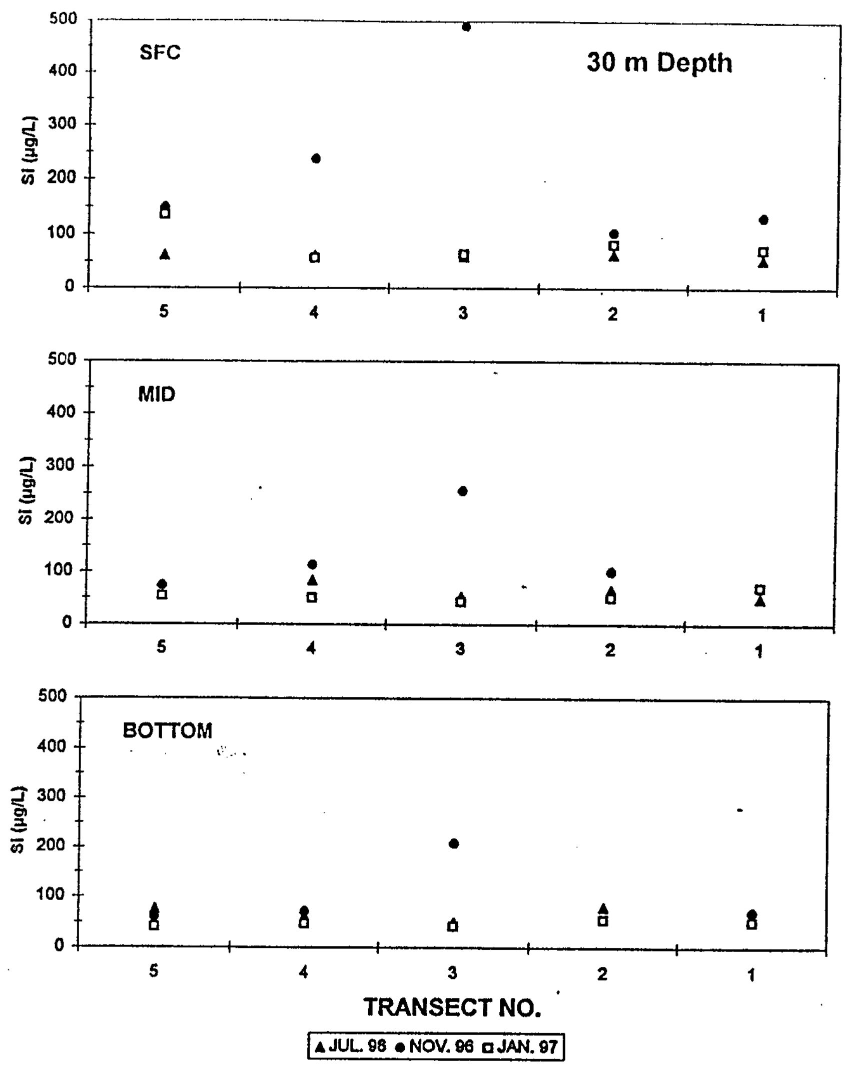


FIGURE 9. Scatter plots showing measurements of silicate in samples collected at the 30m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

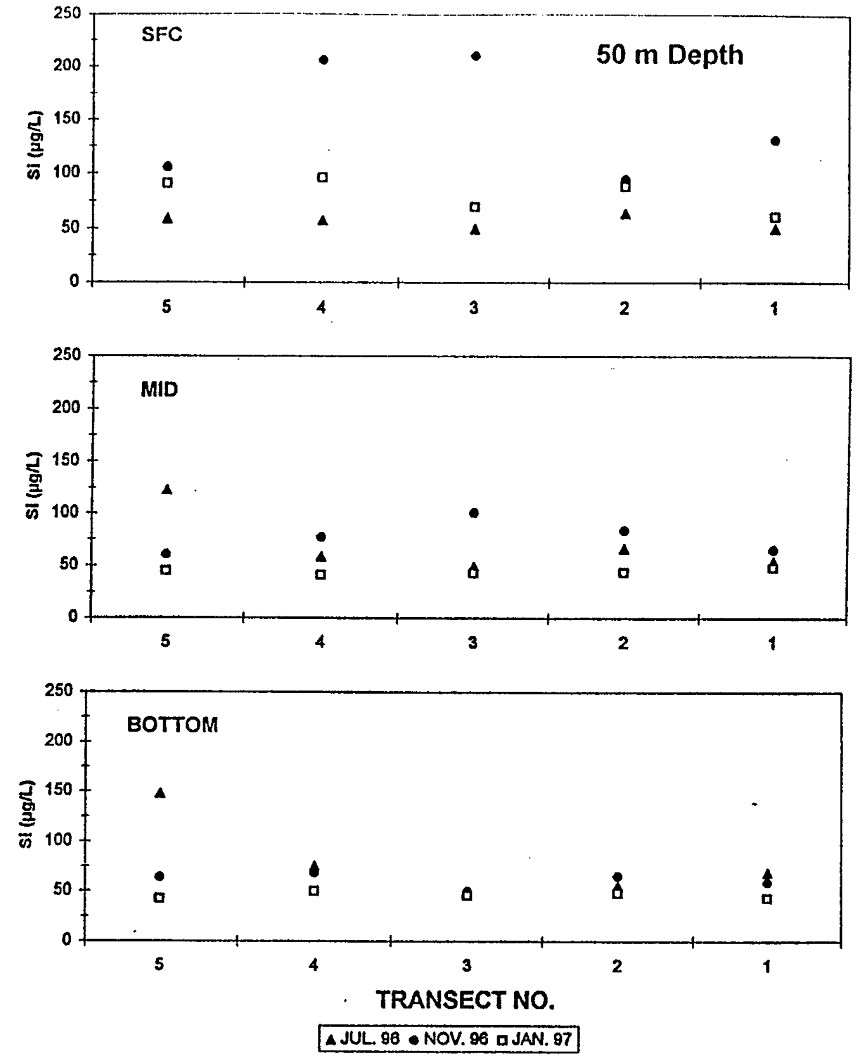


FIGURE 10. Scatter plots showing measurements of silicate in samples collected at the 50m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

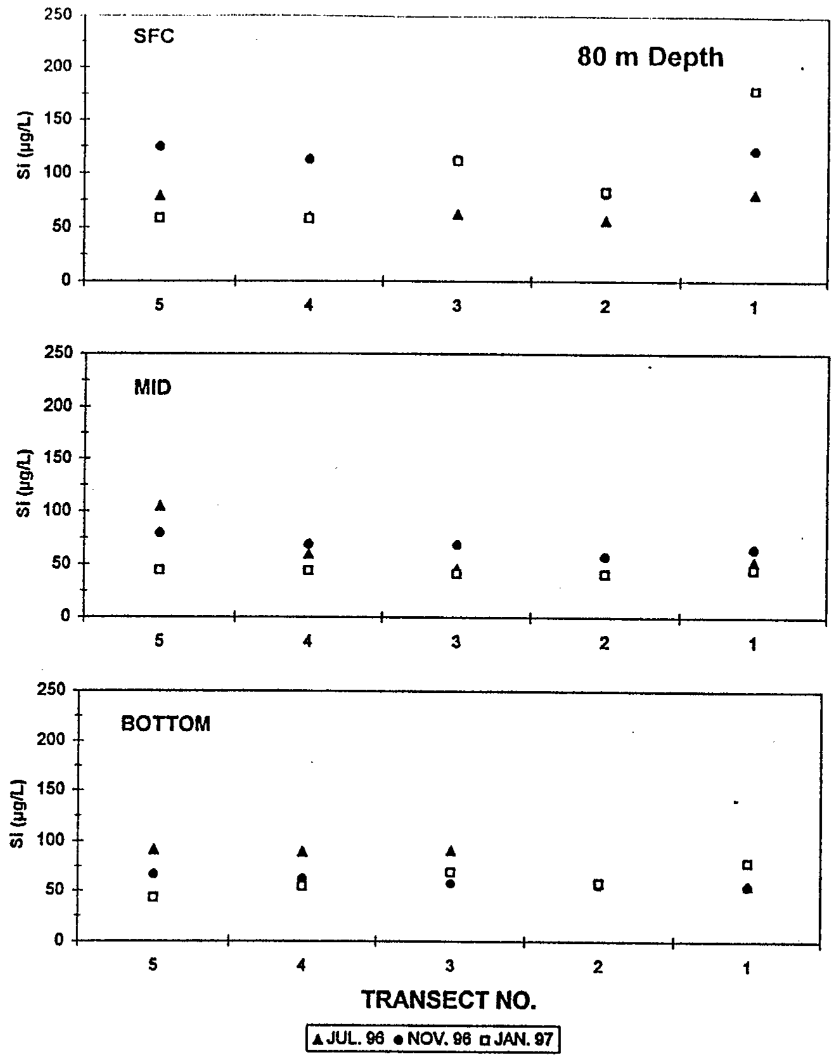


FIGURE 11. Scatter plots showing measurements of silicate in samples collected at the 80m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

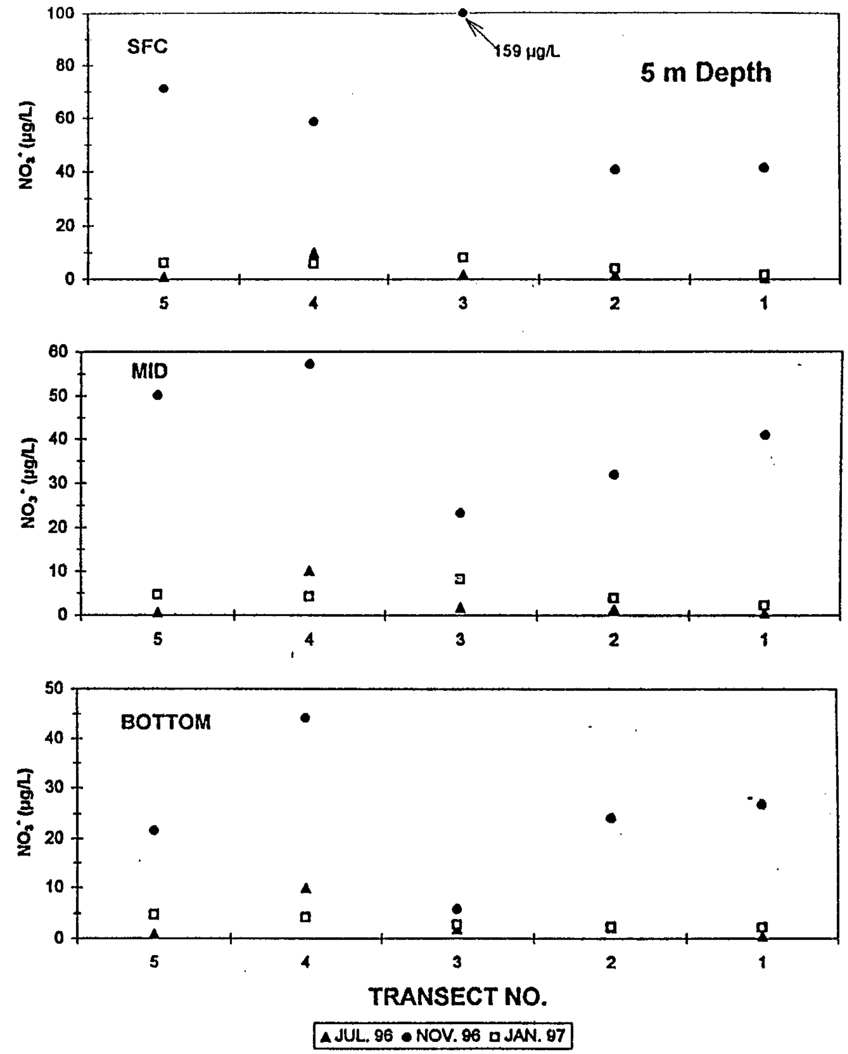


FIGURE 12. Scatter plots showing measurements of nitrate in samples collected at the 5m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. Note Y-axis scale changes. For transect and station locations, see Figure 1.

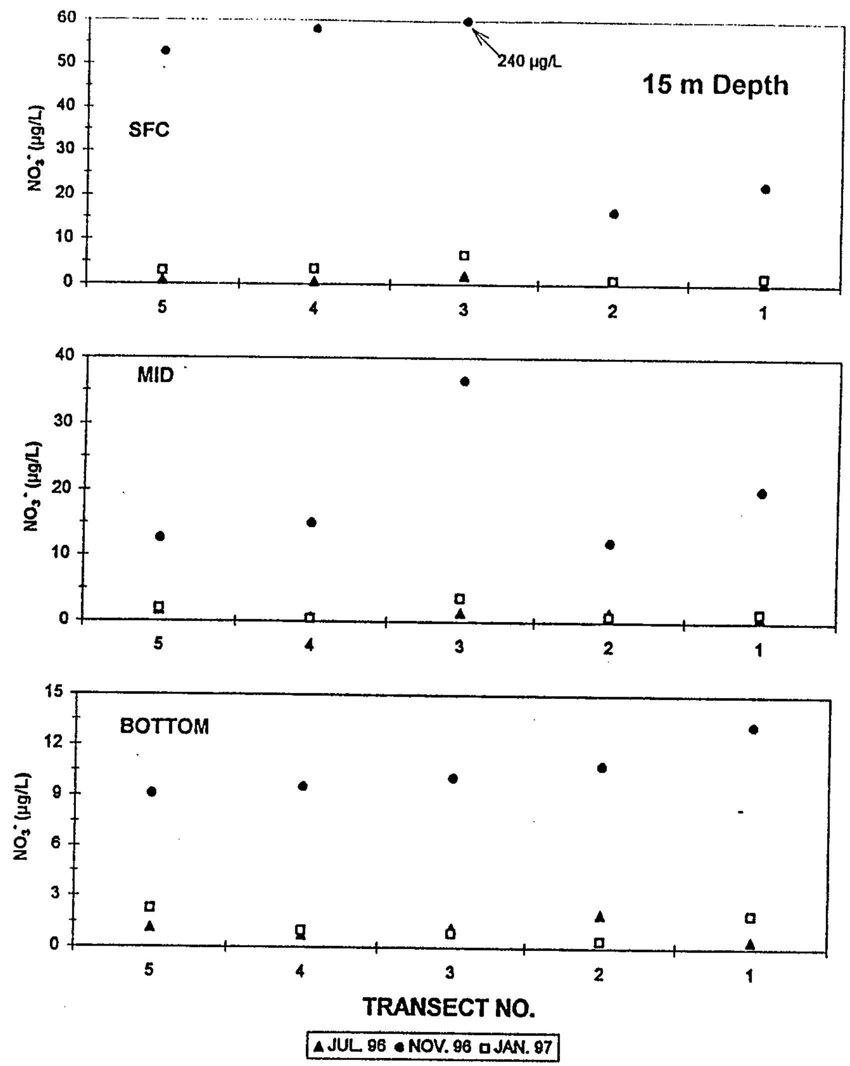


FIGURE 13. Scatter plots showing measurements of nitrate in samples collected at the 15m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. Note Y-axis scale changes. For transect and station locations, see Figure 1.

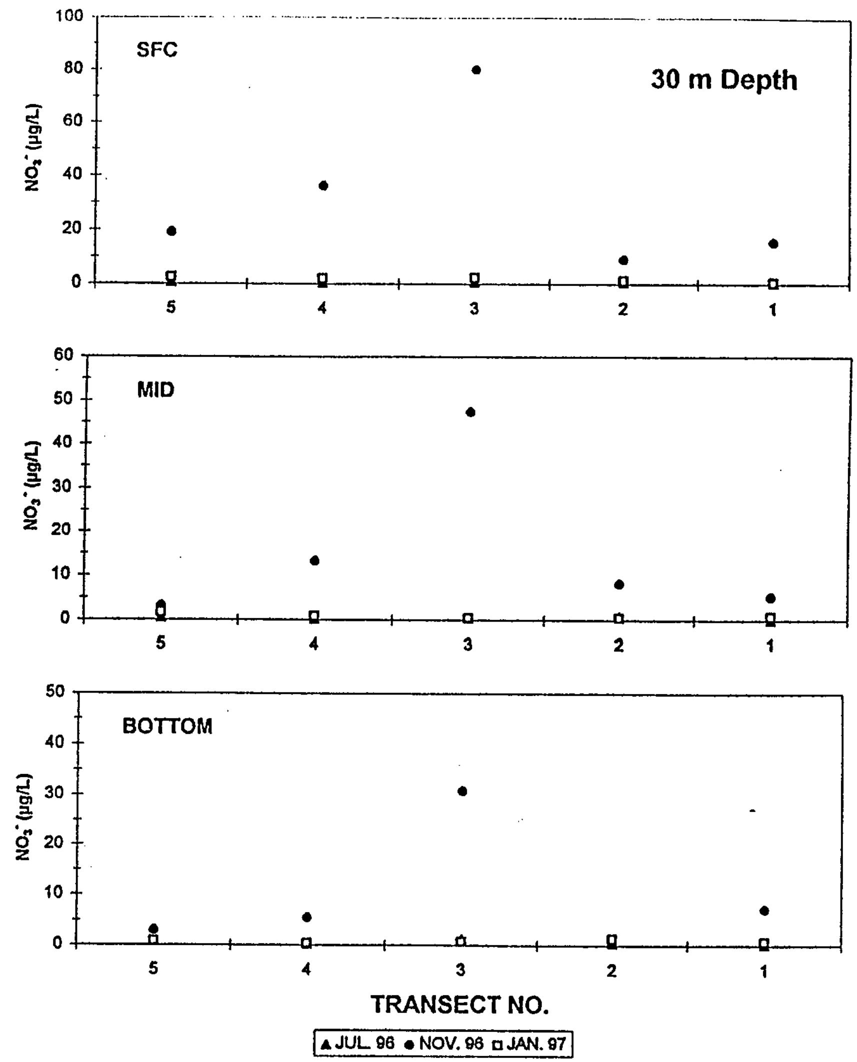


FIGURE 14. Scatter plots showing measurements of nitrate in samples collected at the 30m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

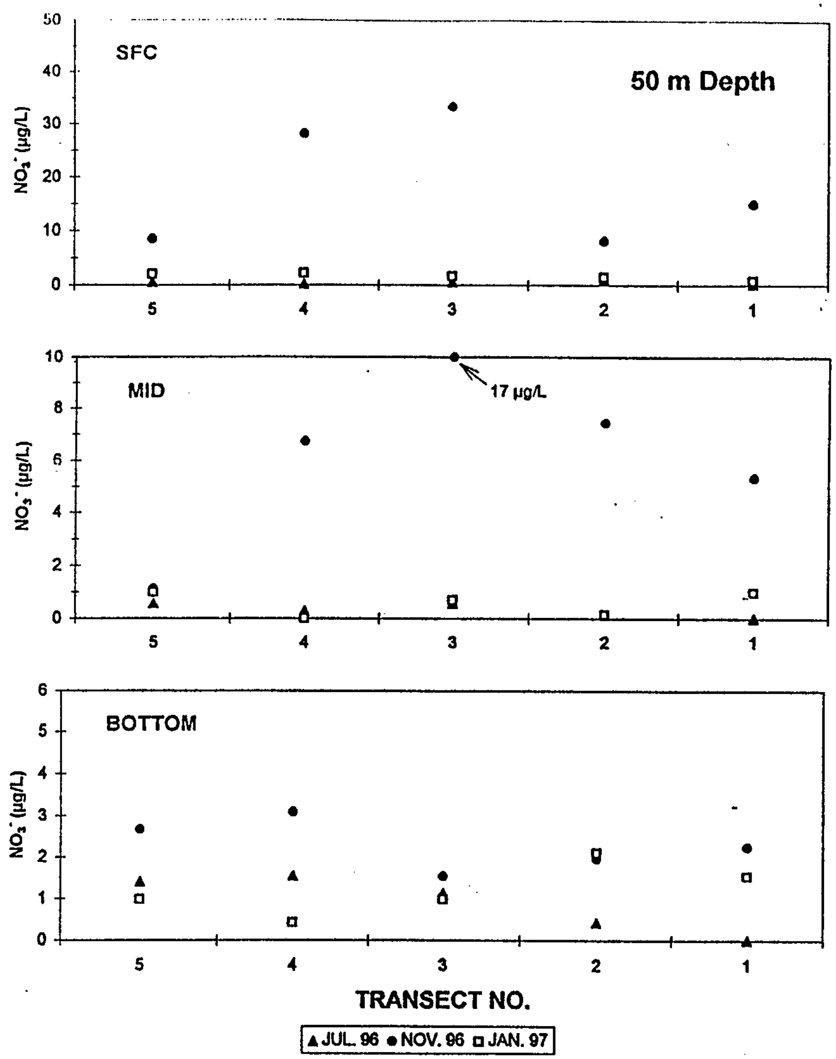


FIGURE 15. Scatter plots showing measurements of nitrate in samples collected at the 50m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. Note Y-axis scale changes. For transect and station locations, see Figure 1.

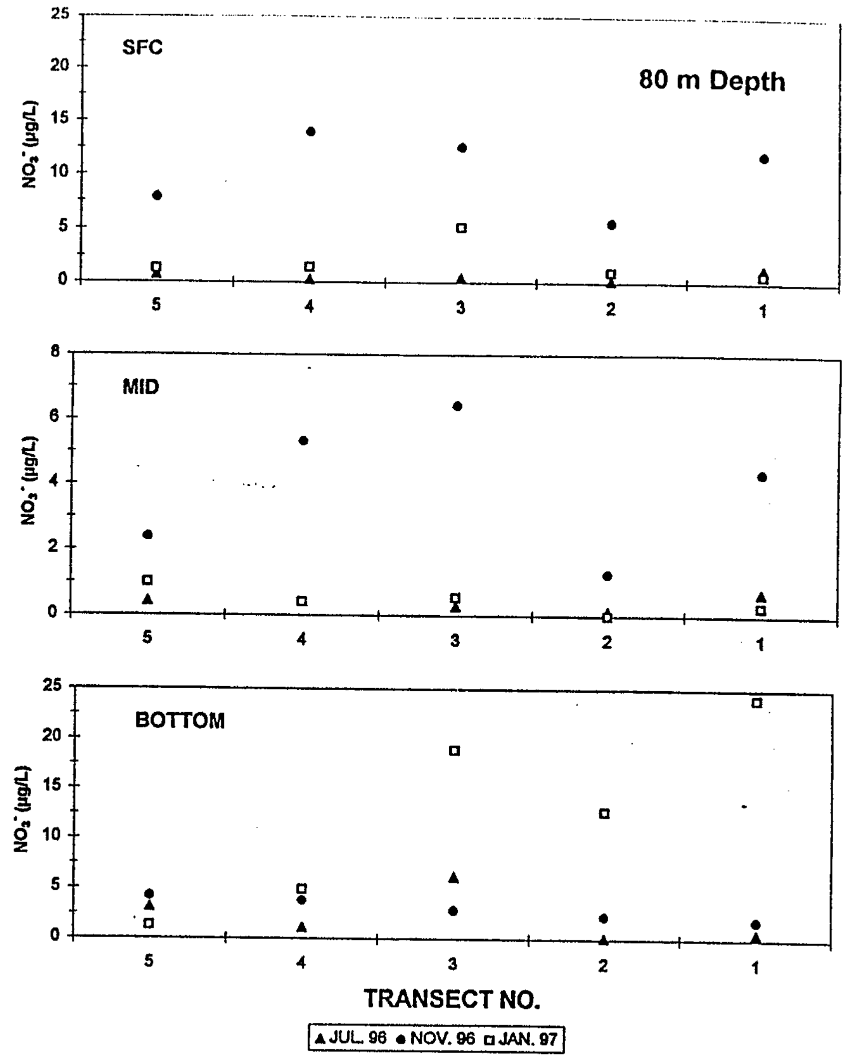


FIGURE 16. Scatter plots showing measurements of nitrate in samples collected at the 80m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. Note Y-axis scale changes. For transect and station locations, see Figure 1.

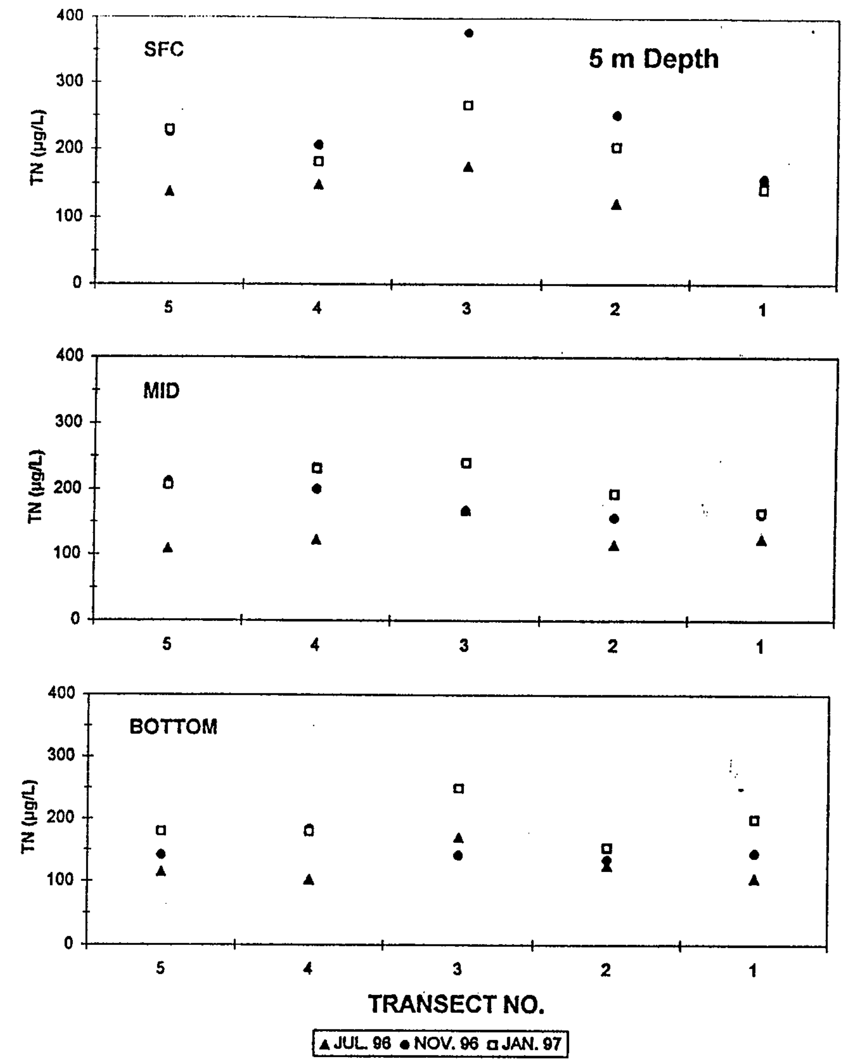


FIGURE 17. Scatter plots showing measurements of total nitrogen in samples collected at the 5m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

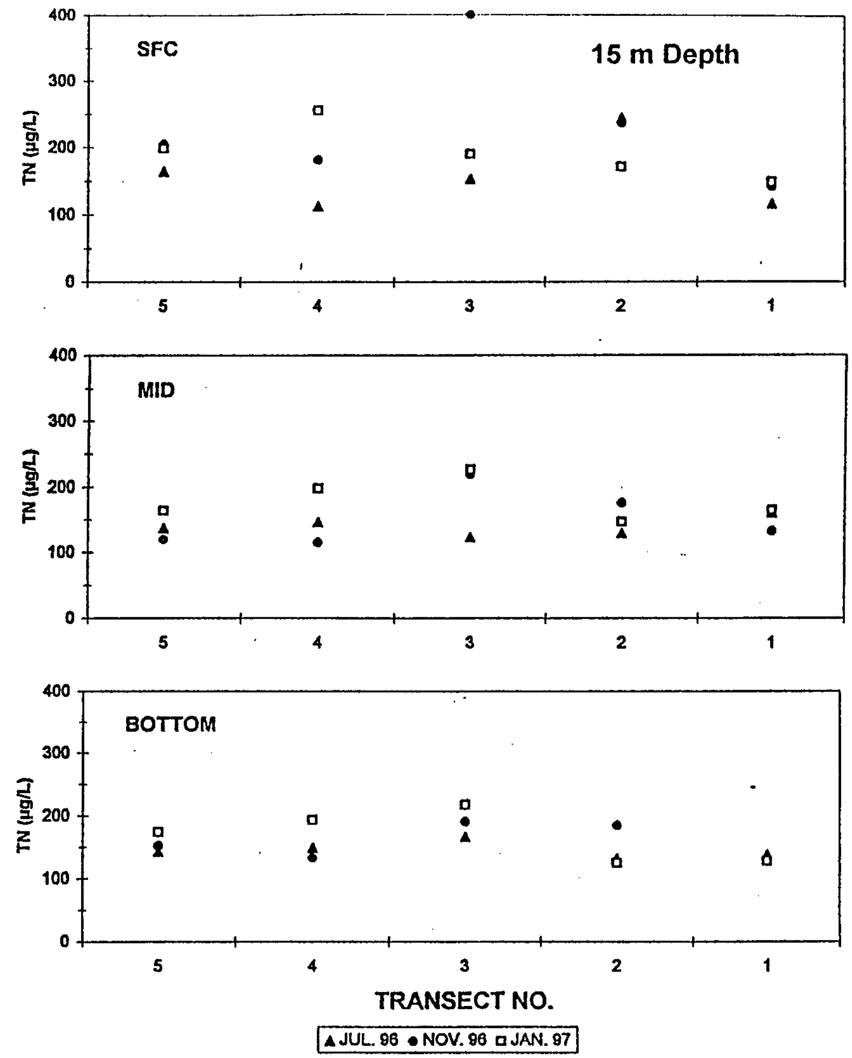


FIGURE 18. Scatter plots showing measurements of total nitrogen in samples collected at the 15m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

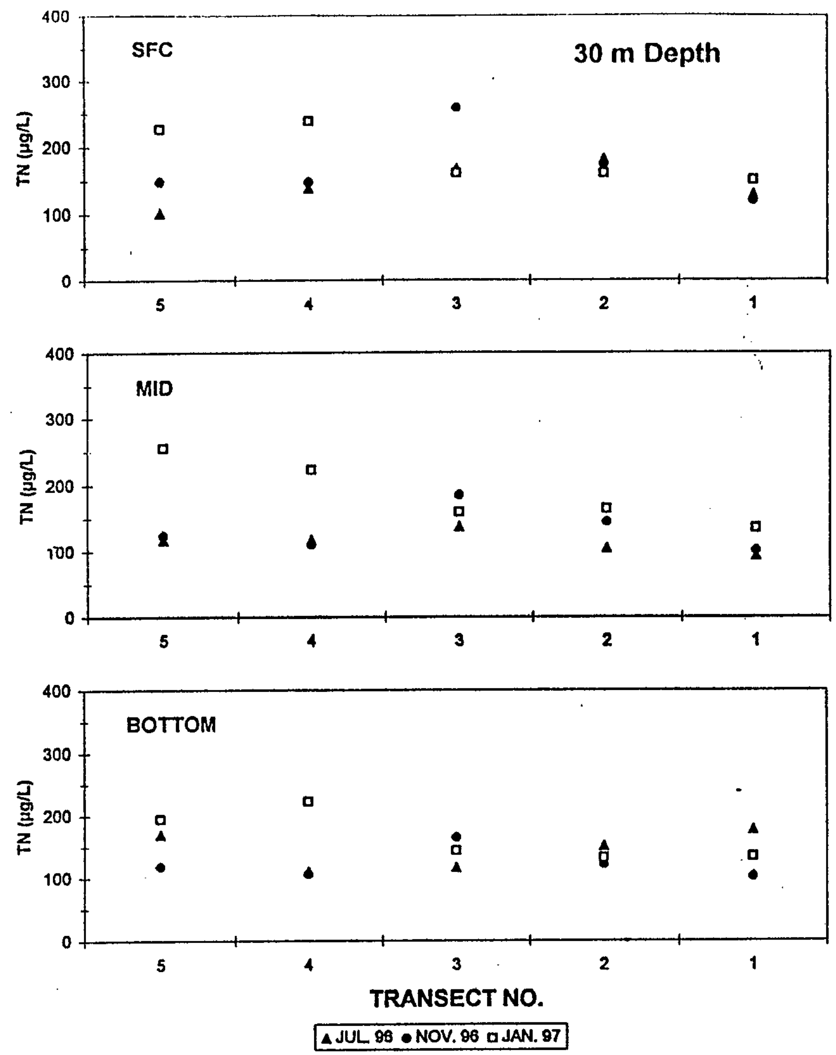


FIGURE 19. Scatter plots showing measurements of total nitrogen in samples collected at the 30m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

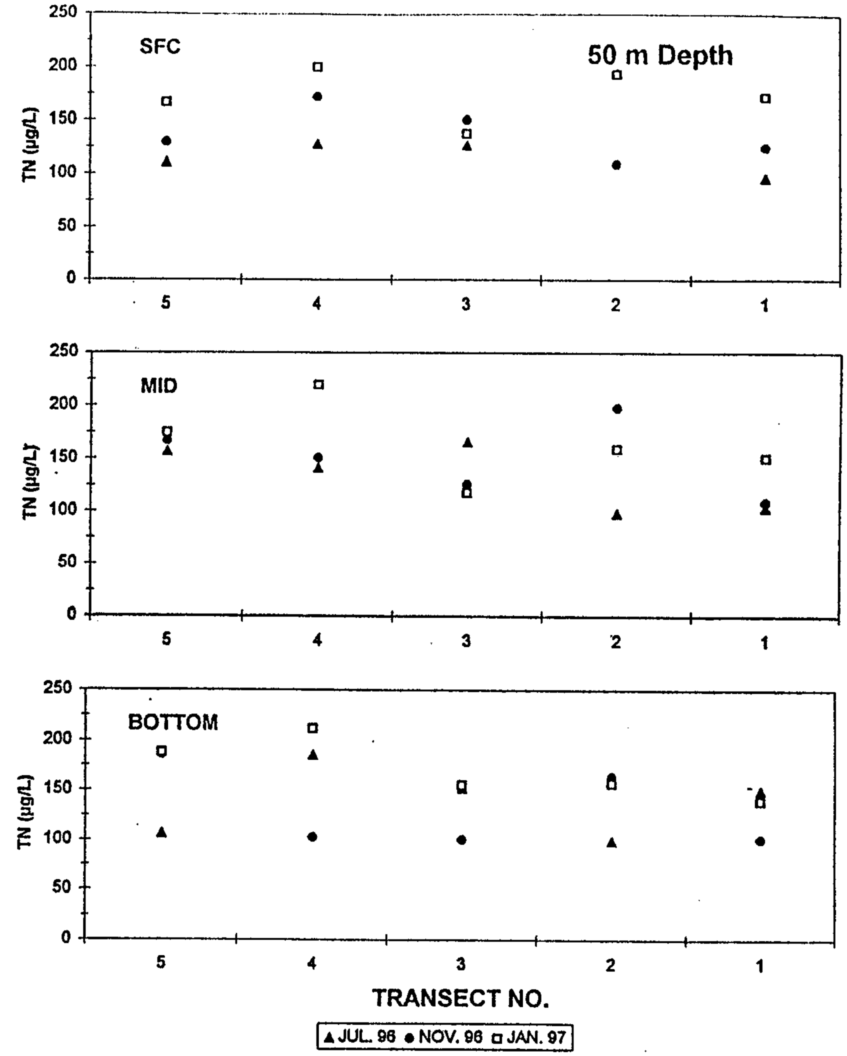


FIGURE 20. Scatter plots showing measurements of total nitrogen in samples collected at the 50m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

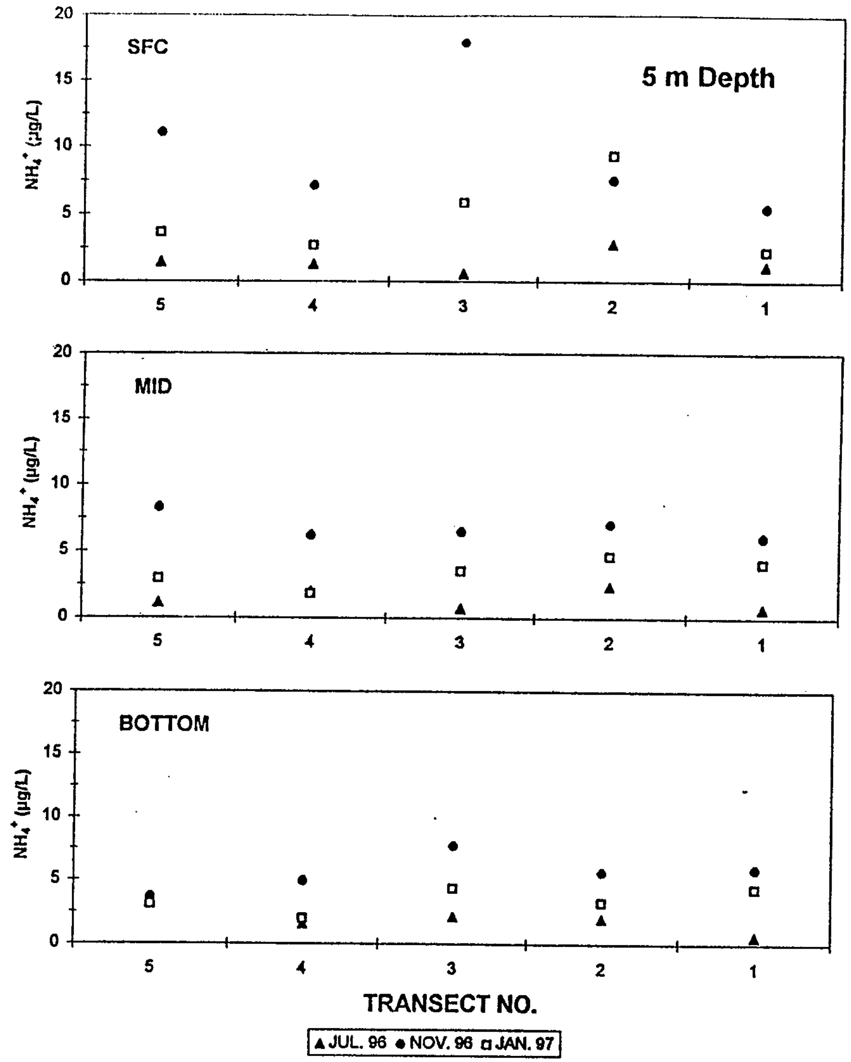


FIGURE 22. Scatter plots showing measurements of ammonium in samples collected at the 5m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

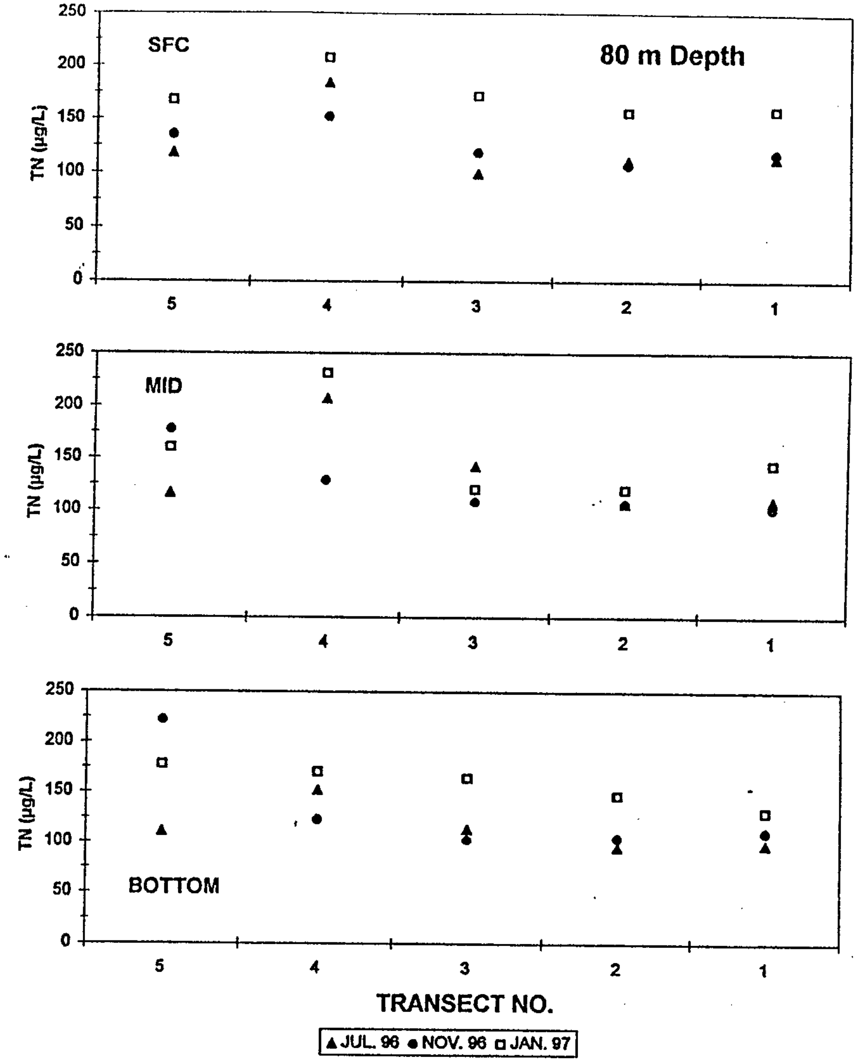


FIGURE 21. Scatter plots showing measurements of total nitrogen in samples collected at the 80m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

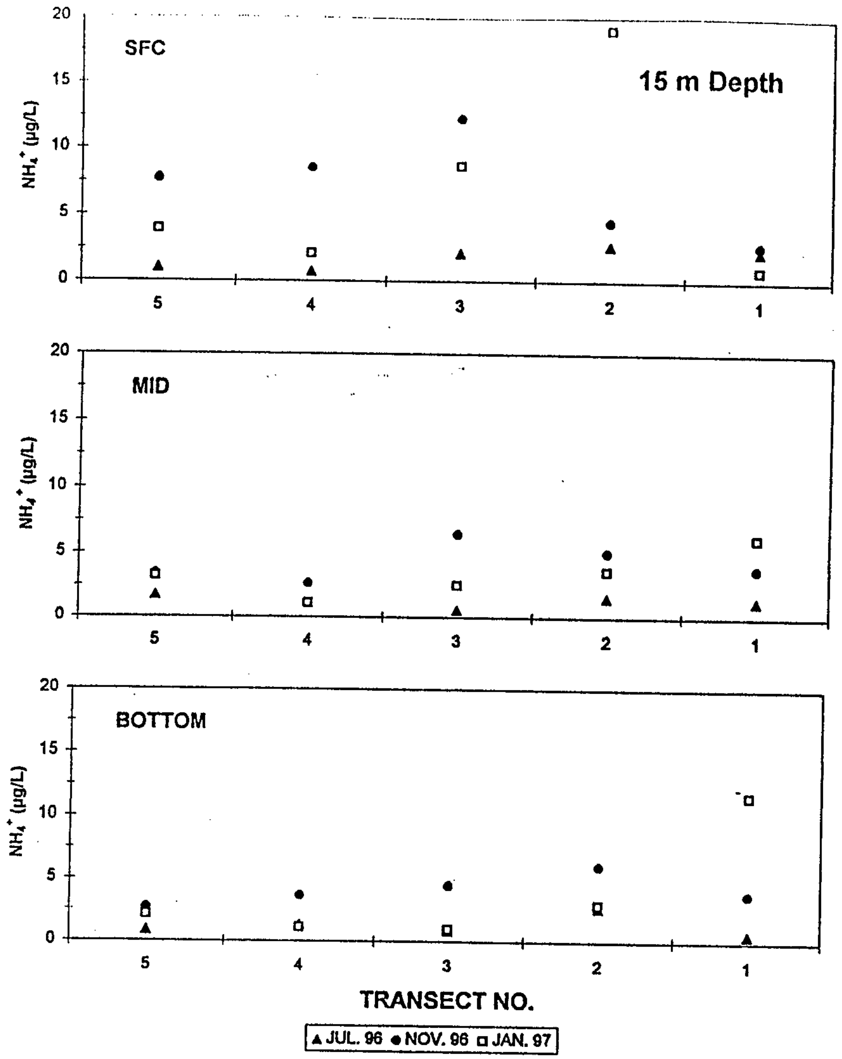


FIGURE 23. Scatter plots showing measurements of ammonium in samples collected at the 15m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

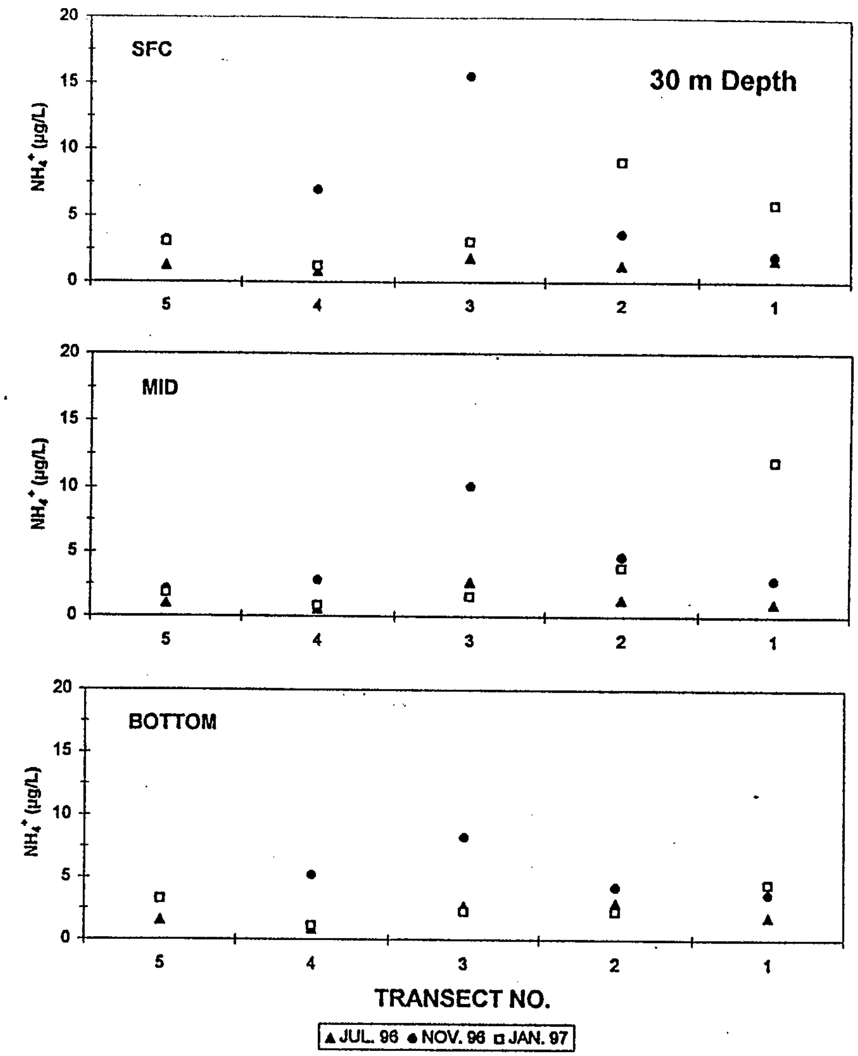


FIGURE 24. Scatter plots showing measurements of ammonium in samples collected at the 30m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

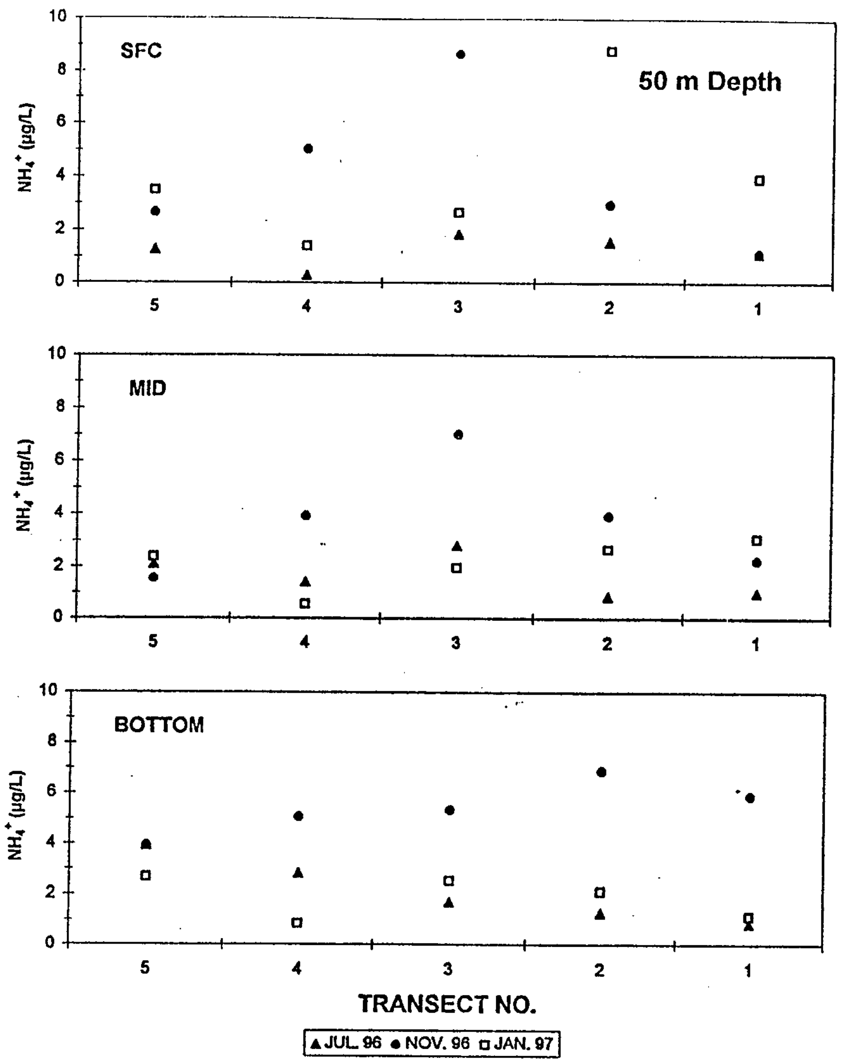


FIGURE 25. Scatter plots showing measurements of ammonium in samples collected at the 50m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

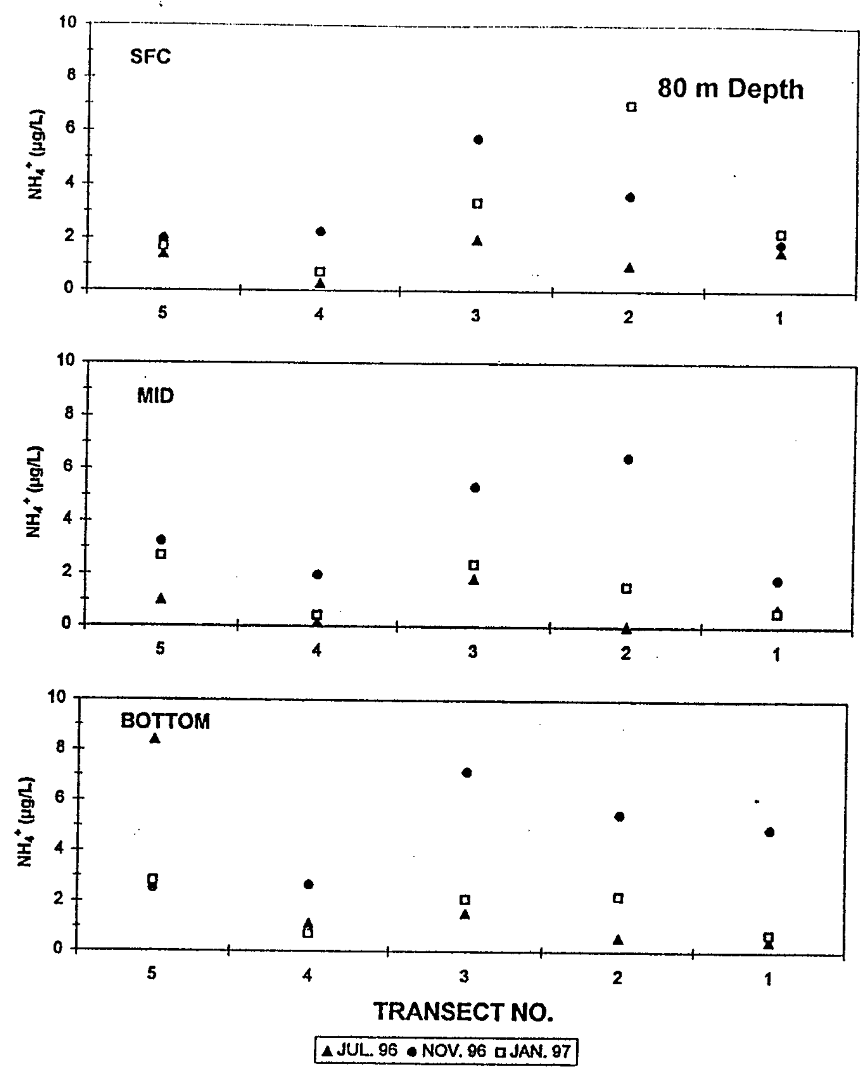


FIGURE 26. Scatter plots showing measurements of ammonium in samples collected at the 80m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

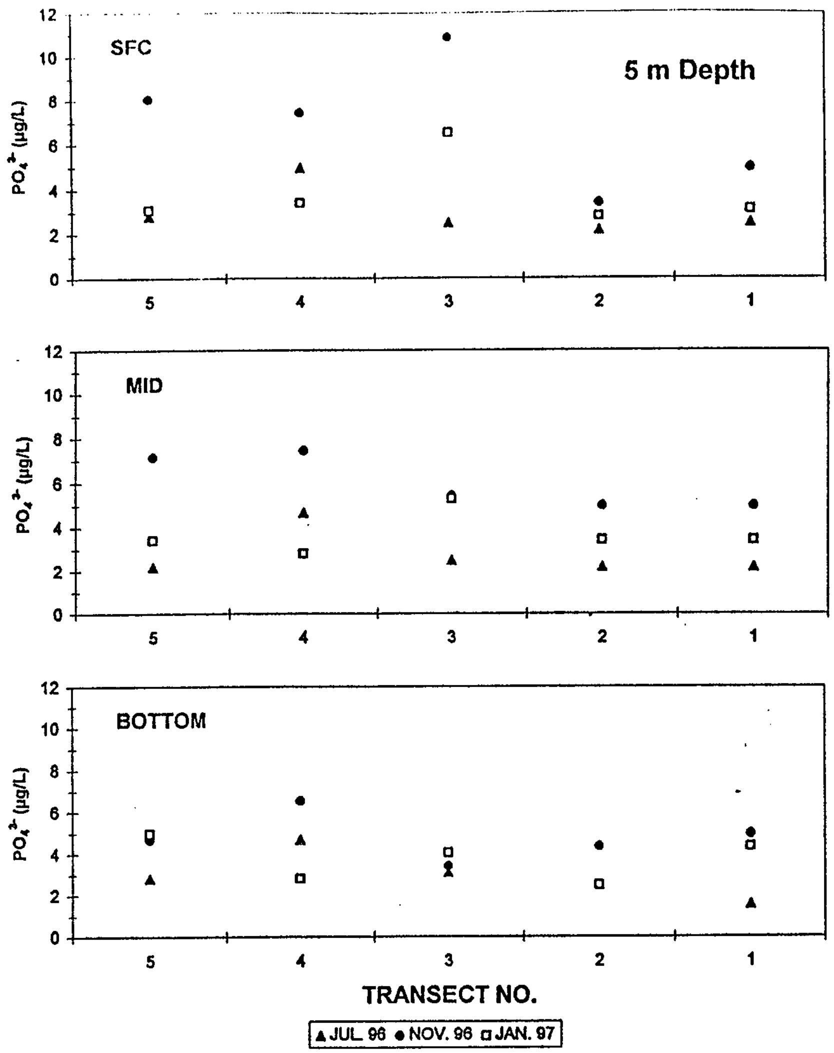


FIGURE 27. Scatter plots showing measurements of phosphate in samples collected at the 5m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

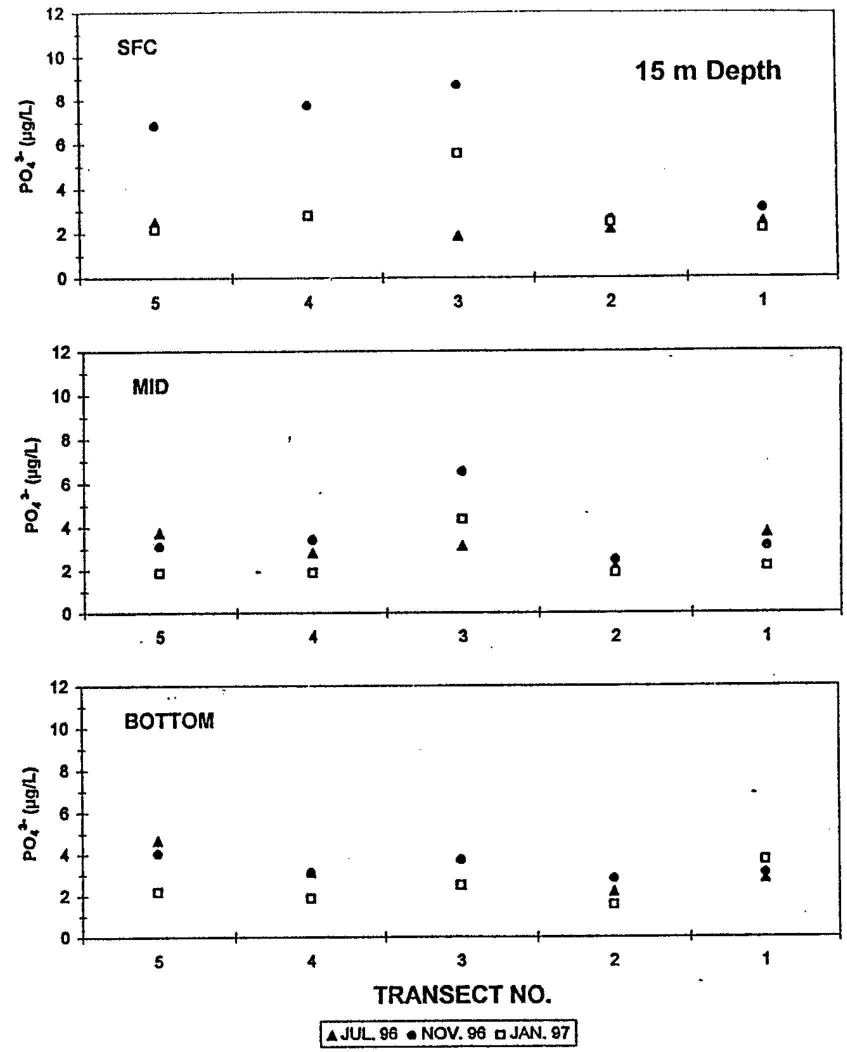


FIGURE 28. Scatter plots showing measurements of phosphate in samples collected at the 15m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

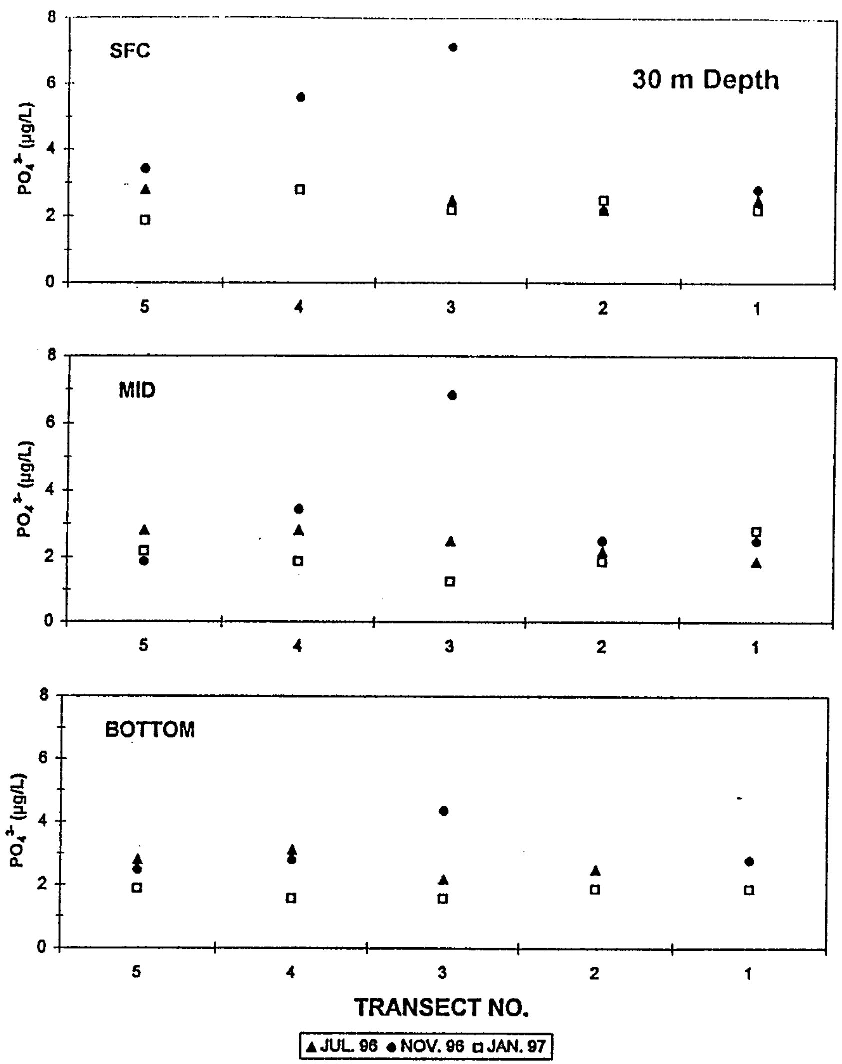


FIGURE 29. Scatter plots showing measurements of phosphate in samples collected at the 30m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. Note Y-axis scale changes. For transect and station locations, see Figure 1.

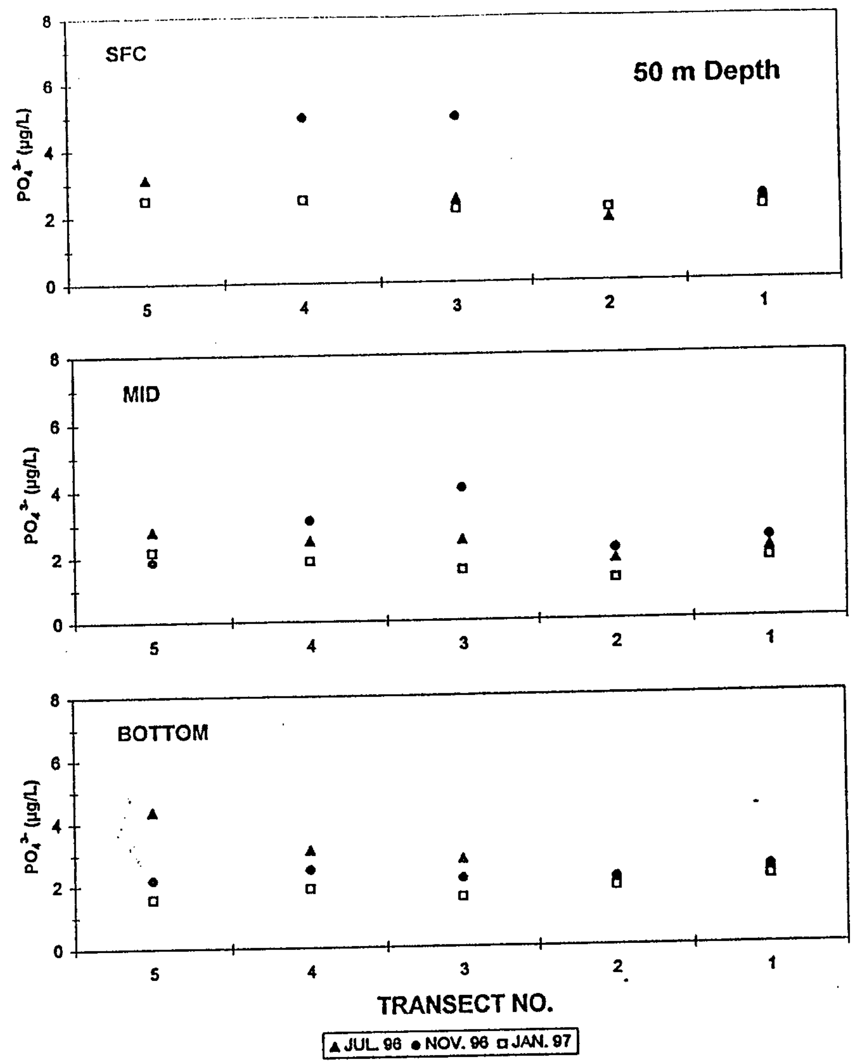


FIGURE 30. Scatter plots showing measurements of phosphate in samples collected at the 50m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

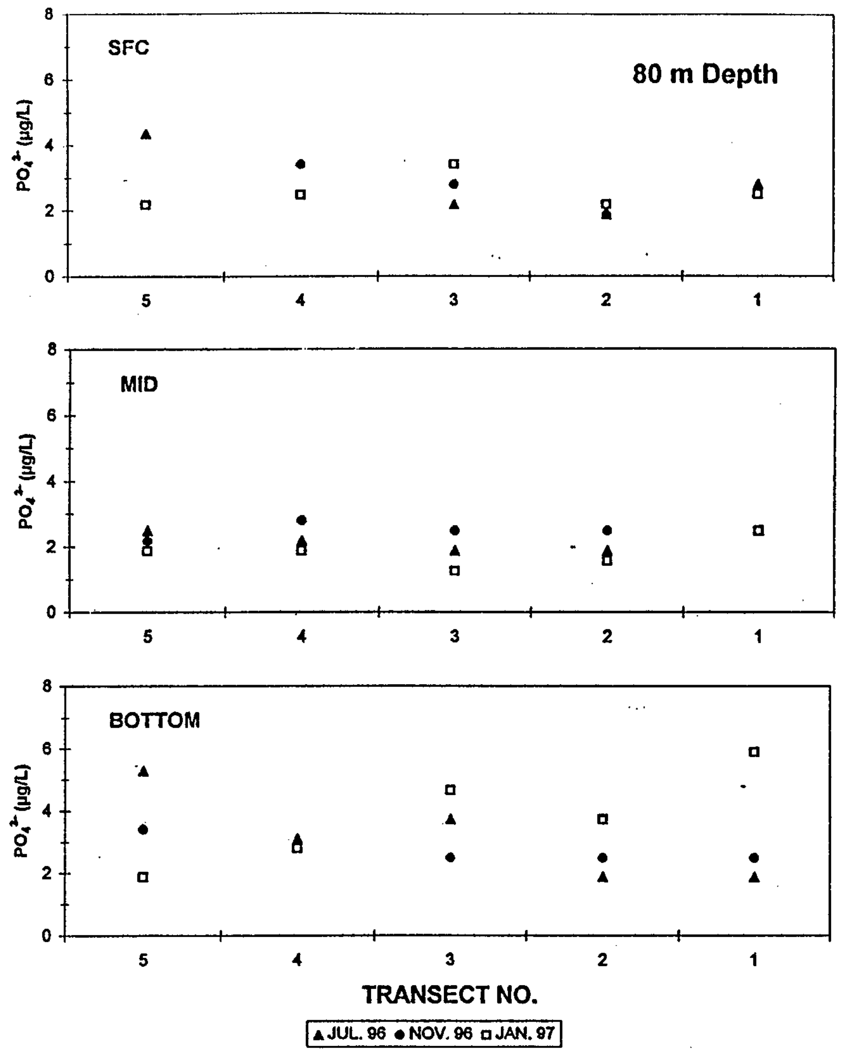


FIGURE 31. Scatter plots showing measurements of phosphate in samples collected at the 80m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

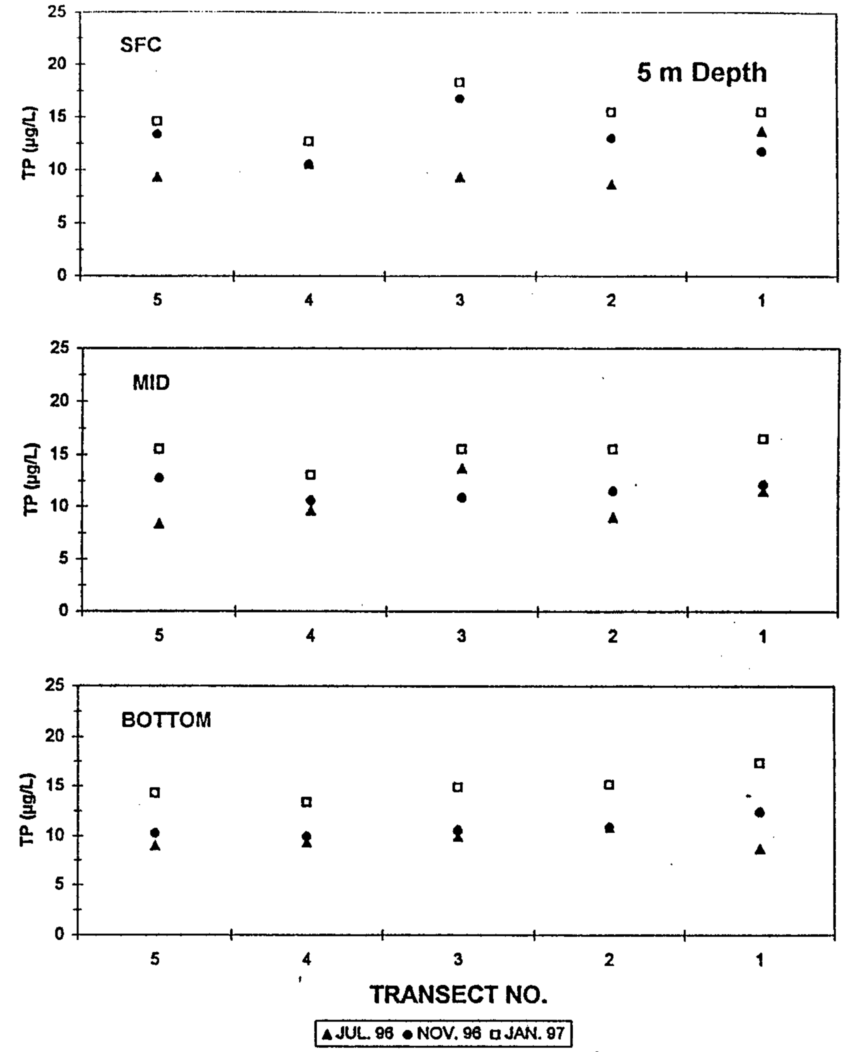


FIGURE 32. Scatter plots showing measurements of total phosphorus in samples collected at the 5m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

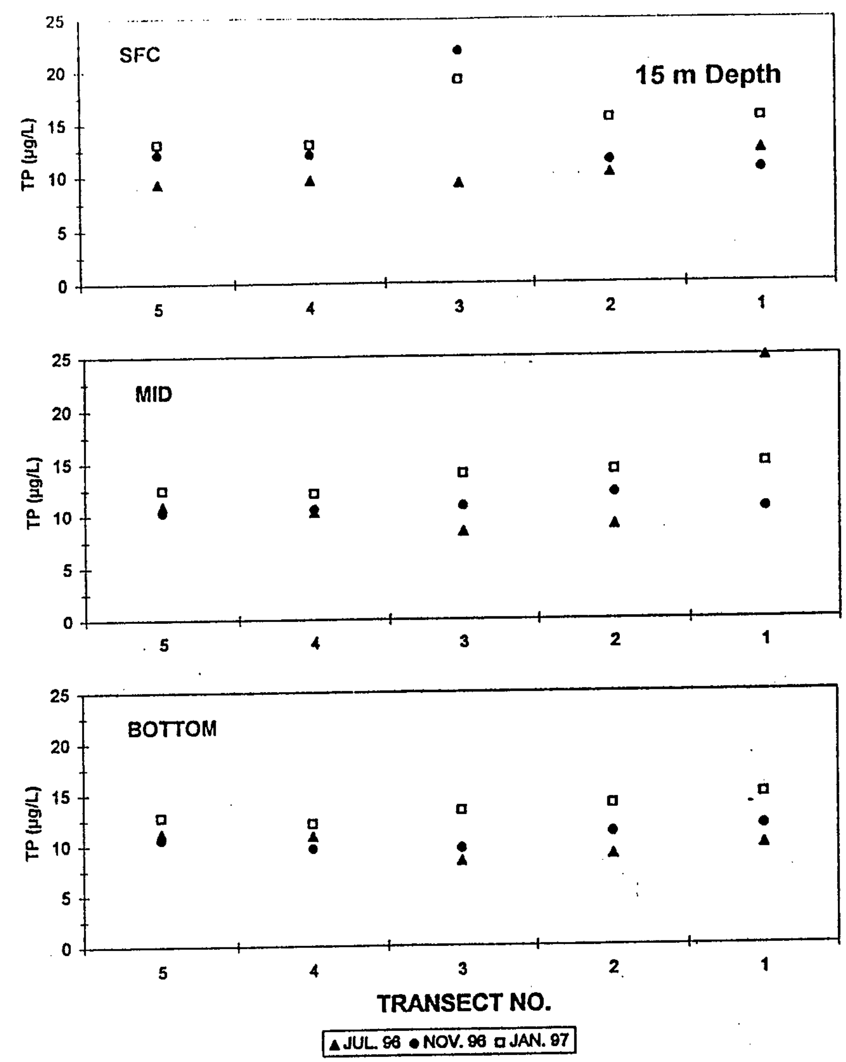


FIGURE 33. Scatter plots showing measurements of total phosphorus in samples collected at the 15m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

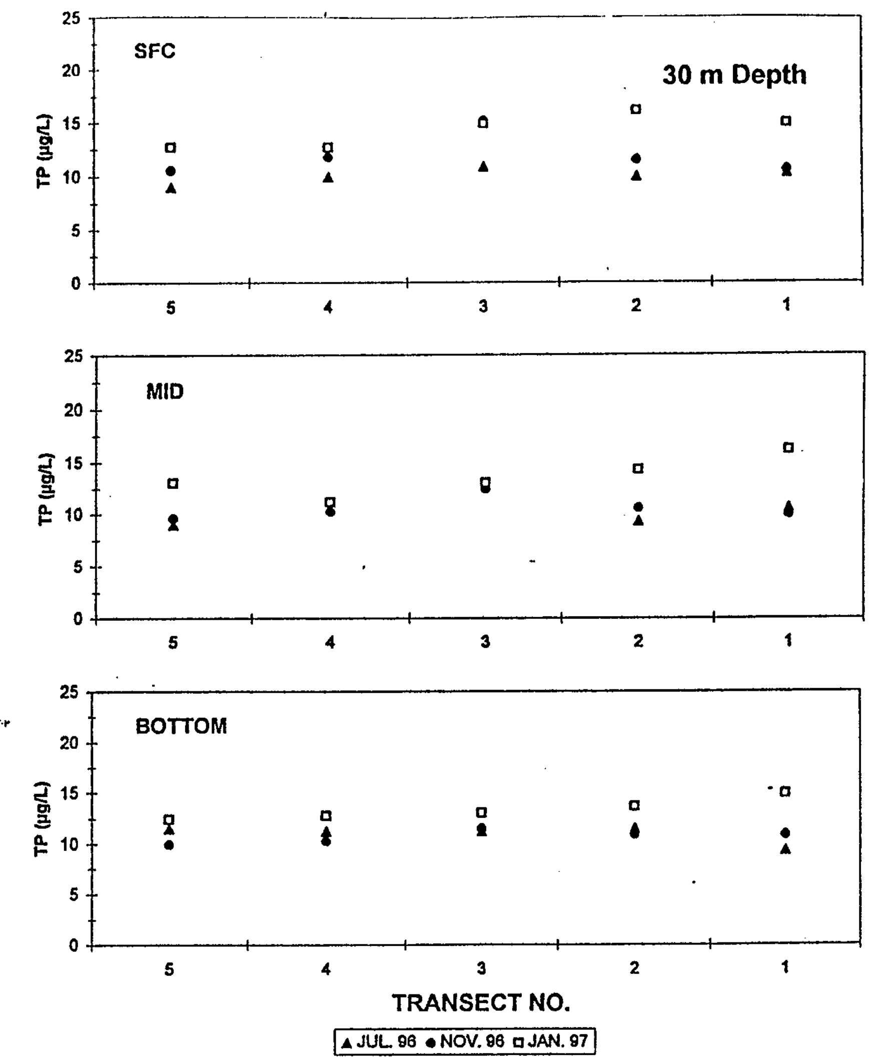


FIGURE 34. Scatter plots showing measurements of total phosphorus in samples collected at the 30m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

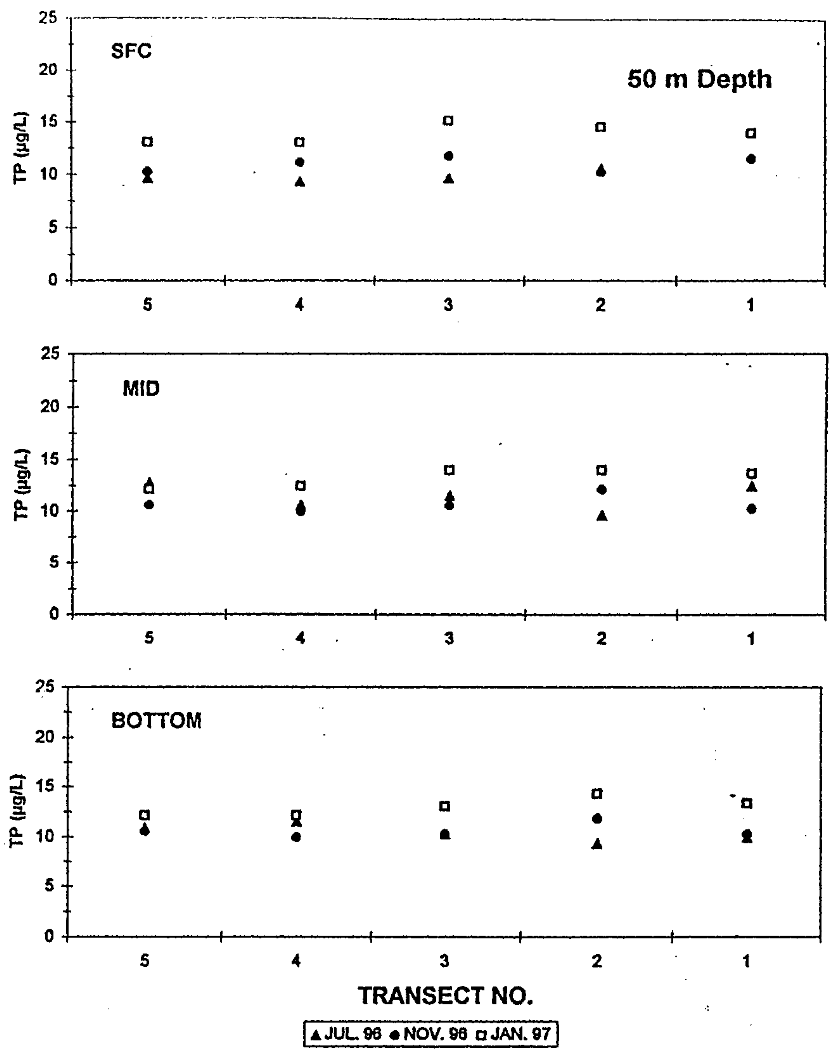


FIGURE 35. Scatter plots showing measurements of total phosphorus in samples collected at the 50m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

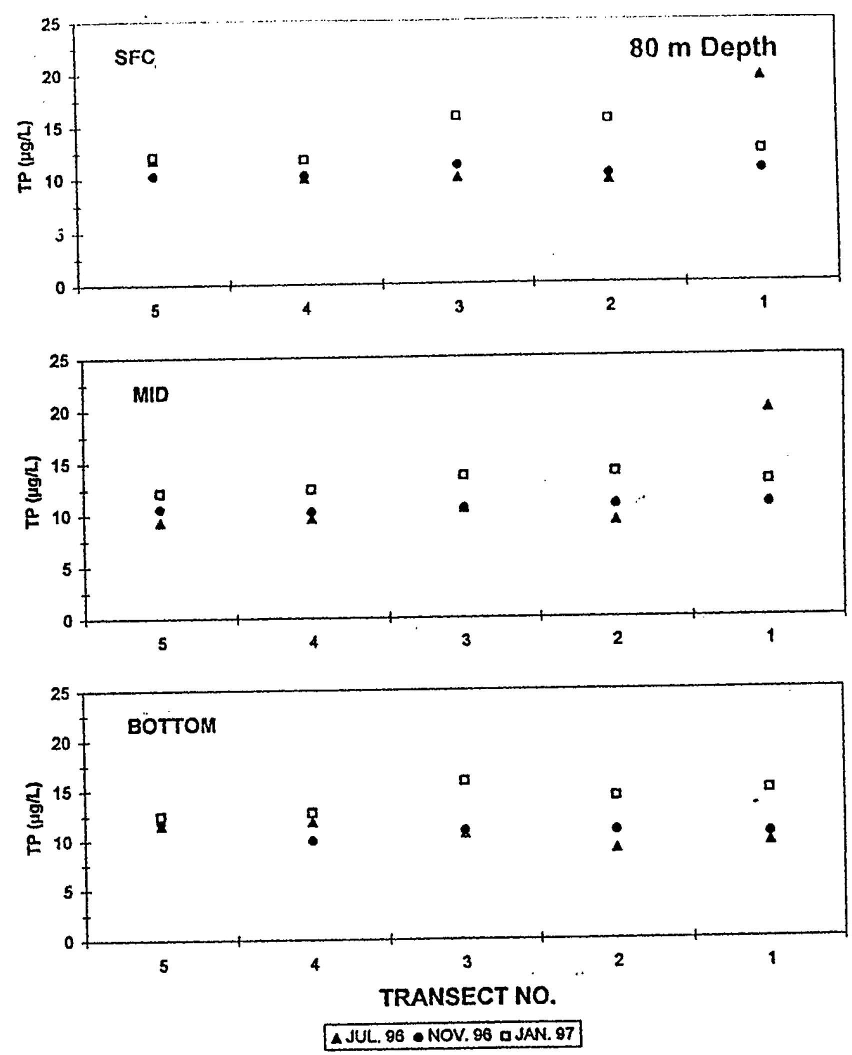


FIGURE 36. Scatter plots showing measurements of total phosphorus in samples collected at the 80m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

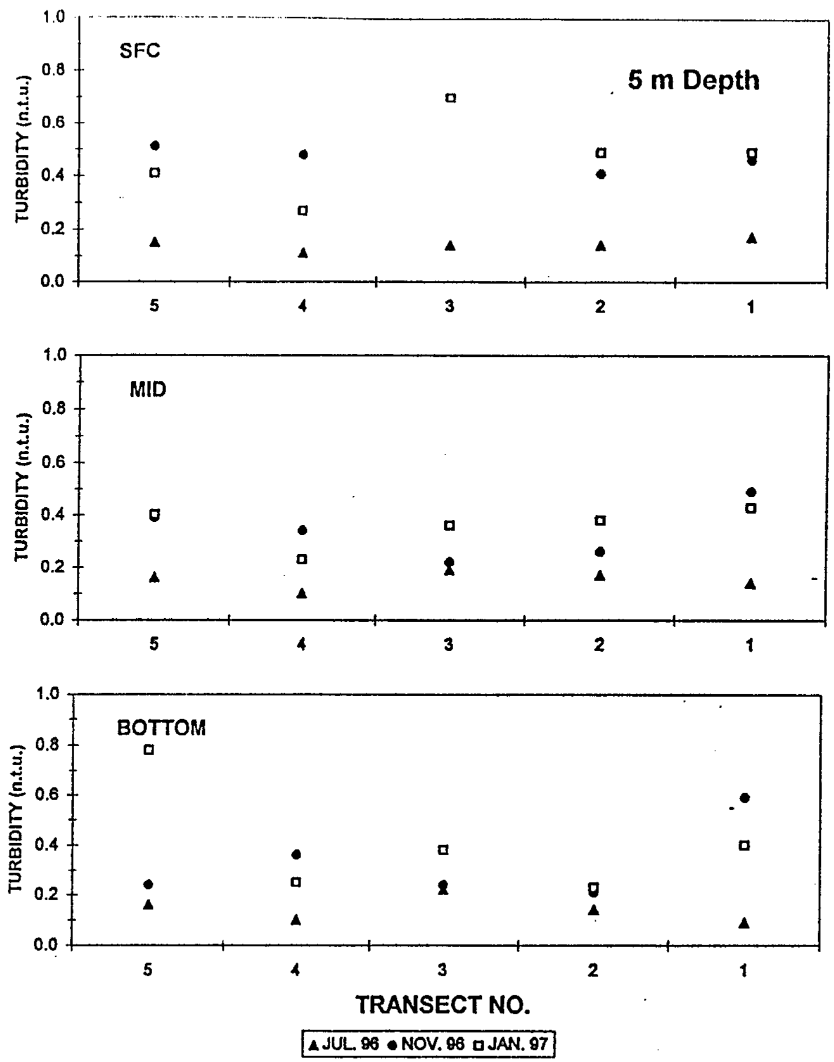


FIGURE 37. Scatter plots showing measurements of turbidity in samples collected at the 5m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

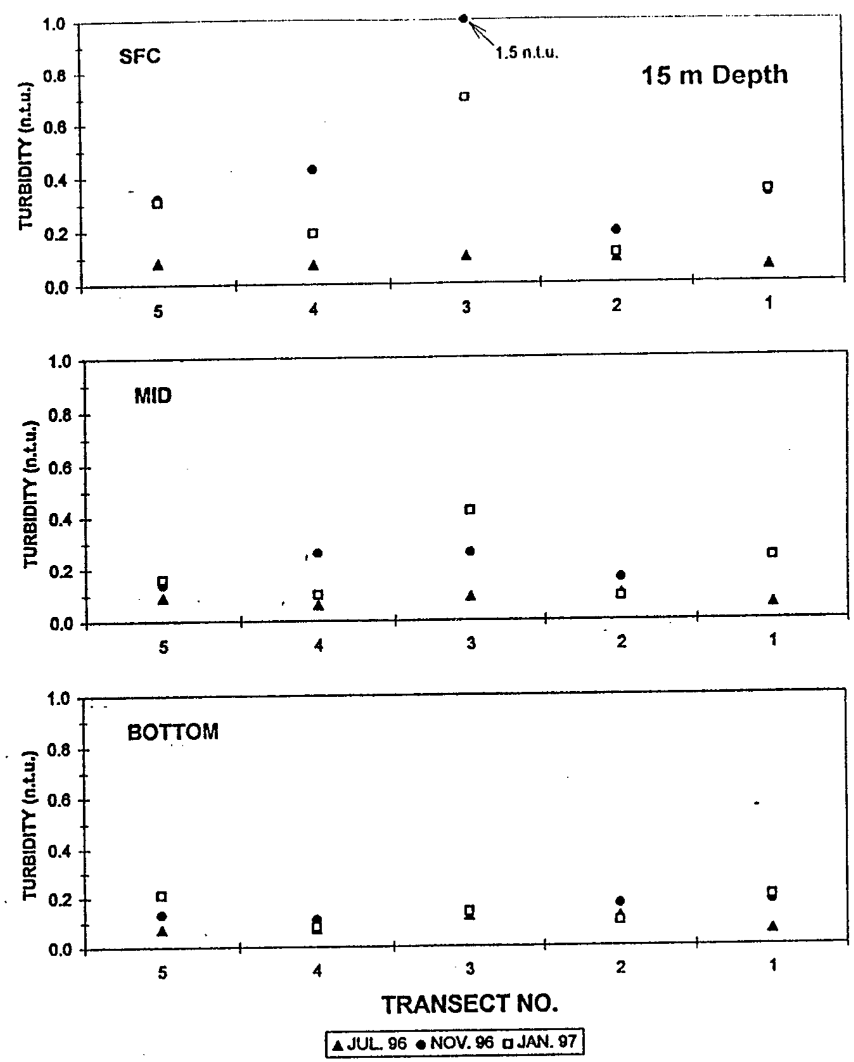


FIGURE 38. Scatter plots showing measurements of turbidity in samples collected at the 15m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

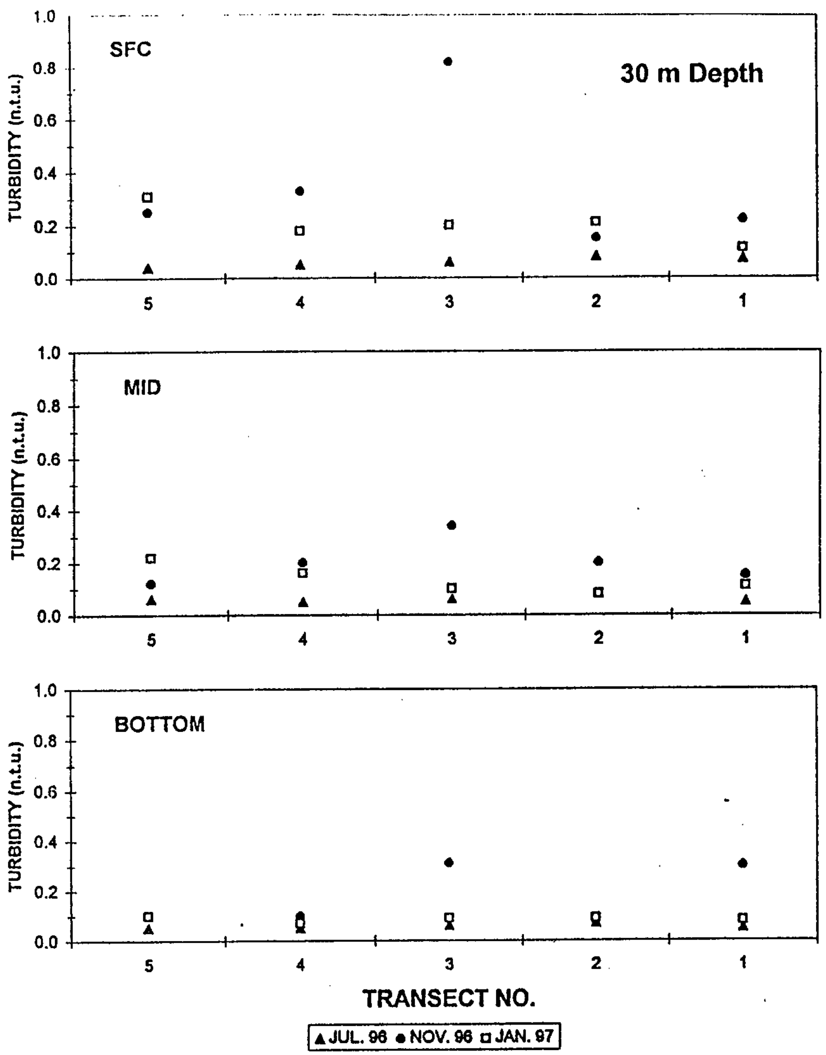


FIGURE 39. Scatter plots showing measurements of turbidity in samples collected at the 30m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

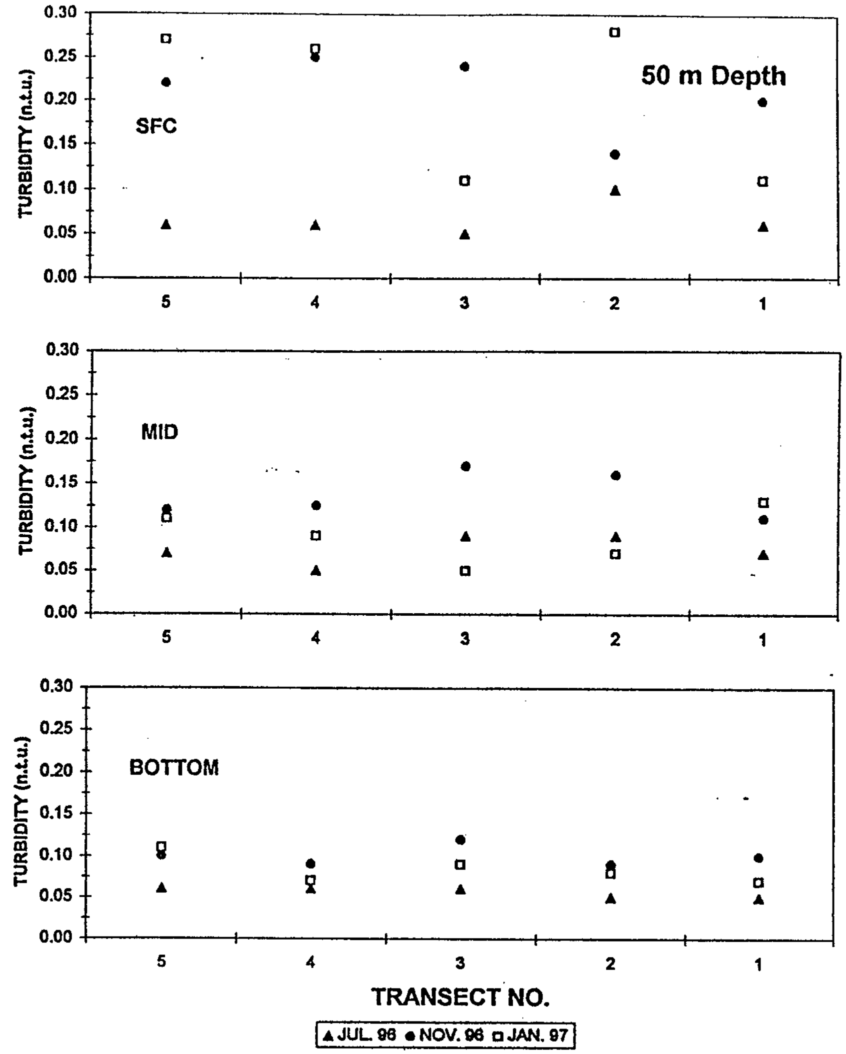


FIGURE 40. Scatter plots showing measurements of turbidity in samples collected at the 50m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

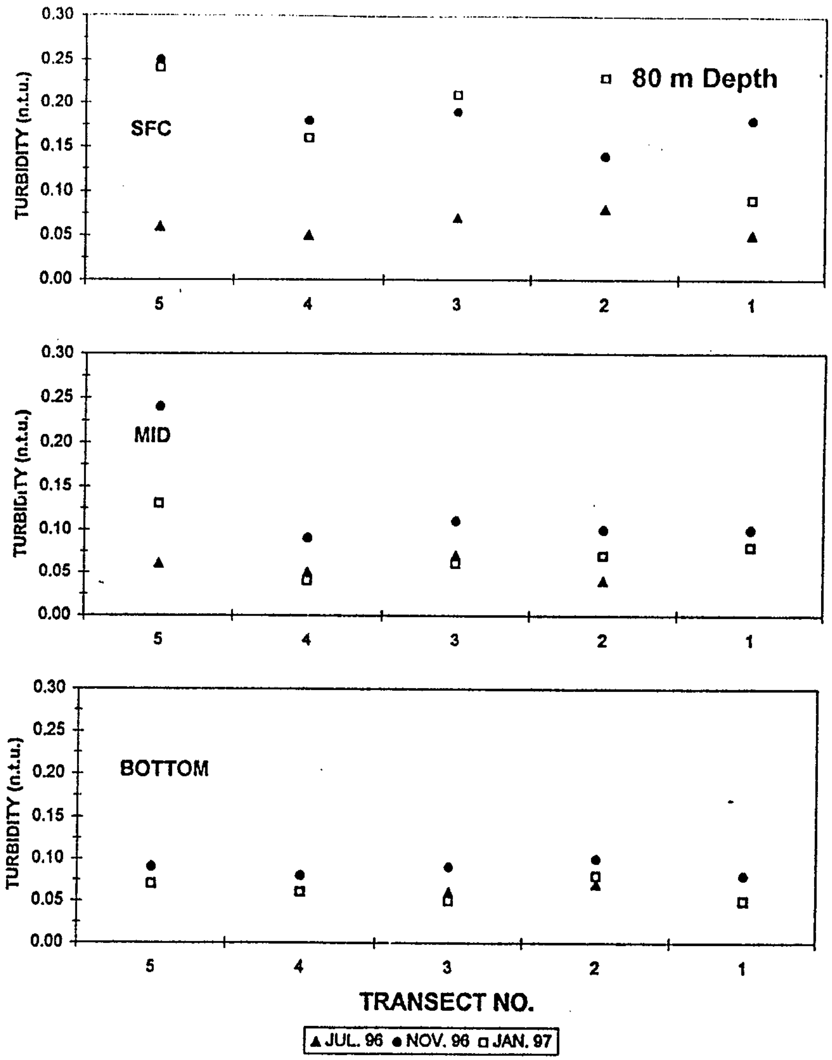


FIGURE 41. Scatter plots showing measurements of turbidity in samples collected at the 80m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

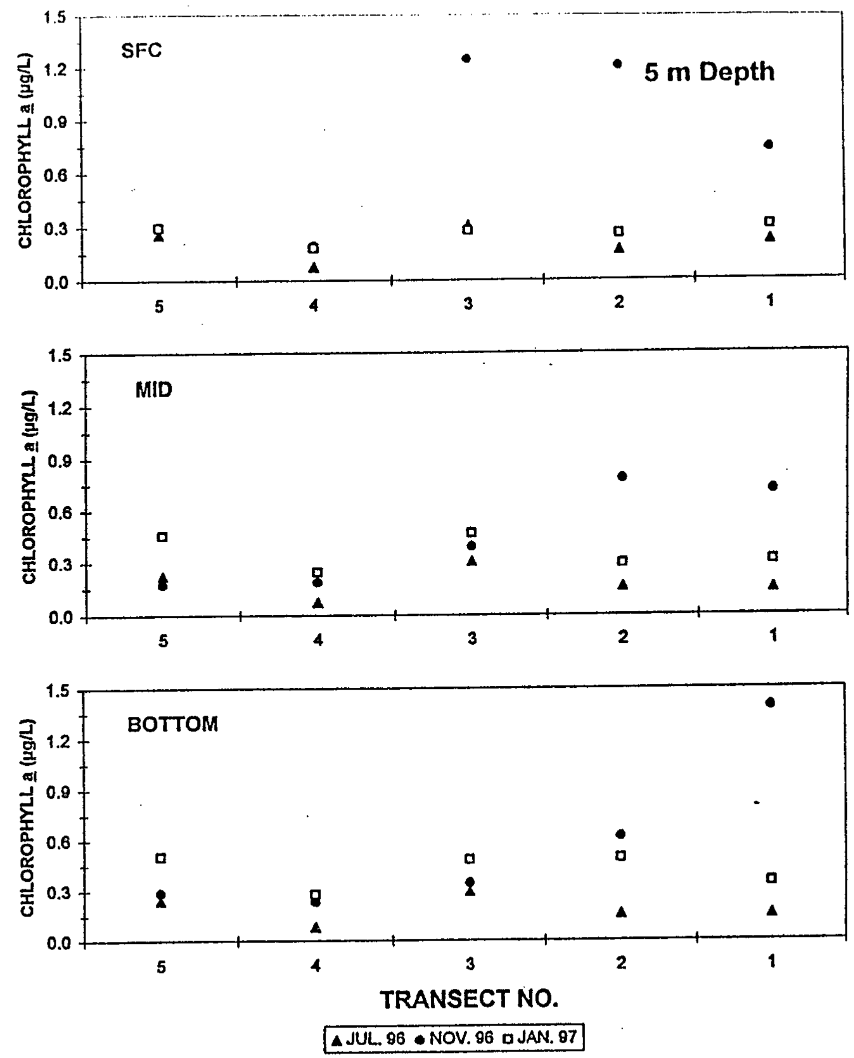


FIGURE 42. Scatter plots showing measurements of chlorophyll a in samples collected at the 5m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate We;t (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

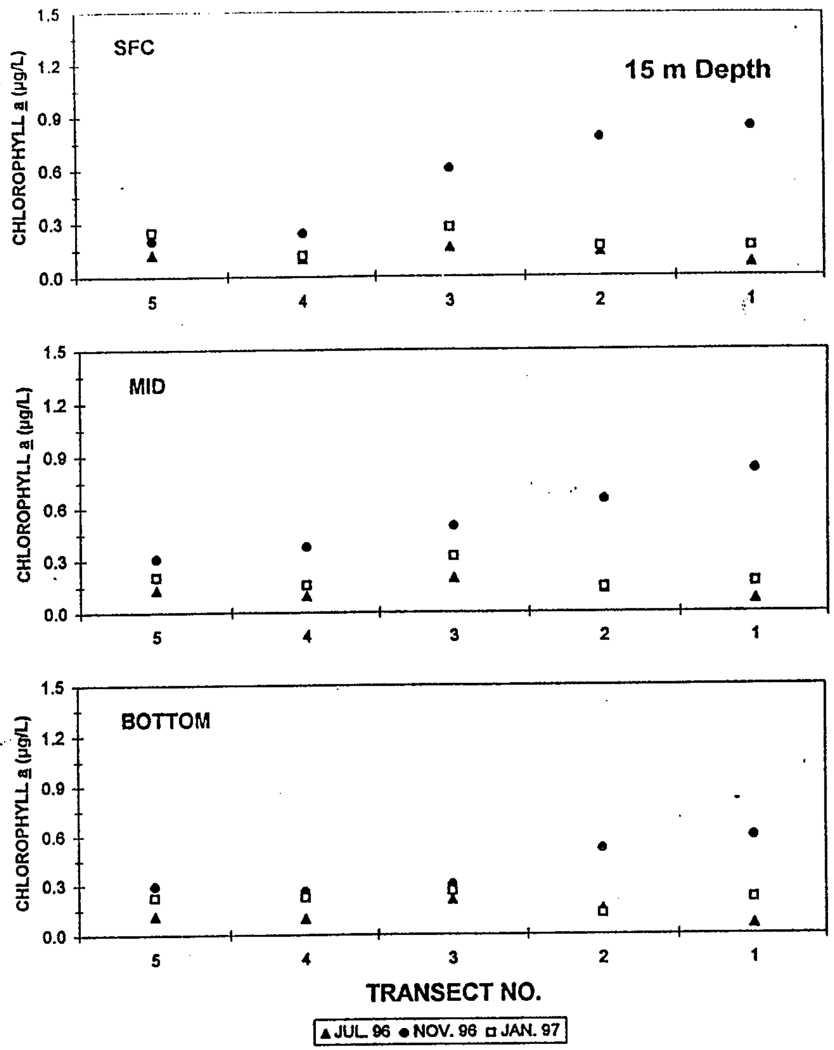


FIGURE 43. Scatter plots showing measurements of chlorophyll a in samples collected at the 15m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

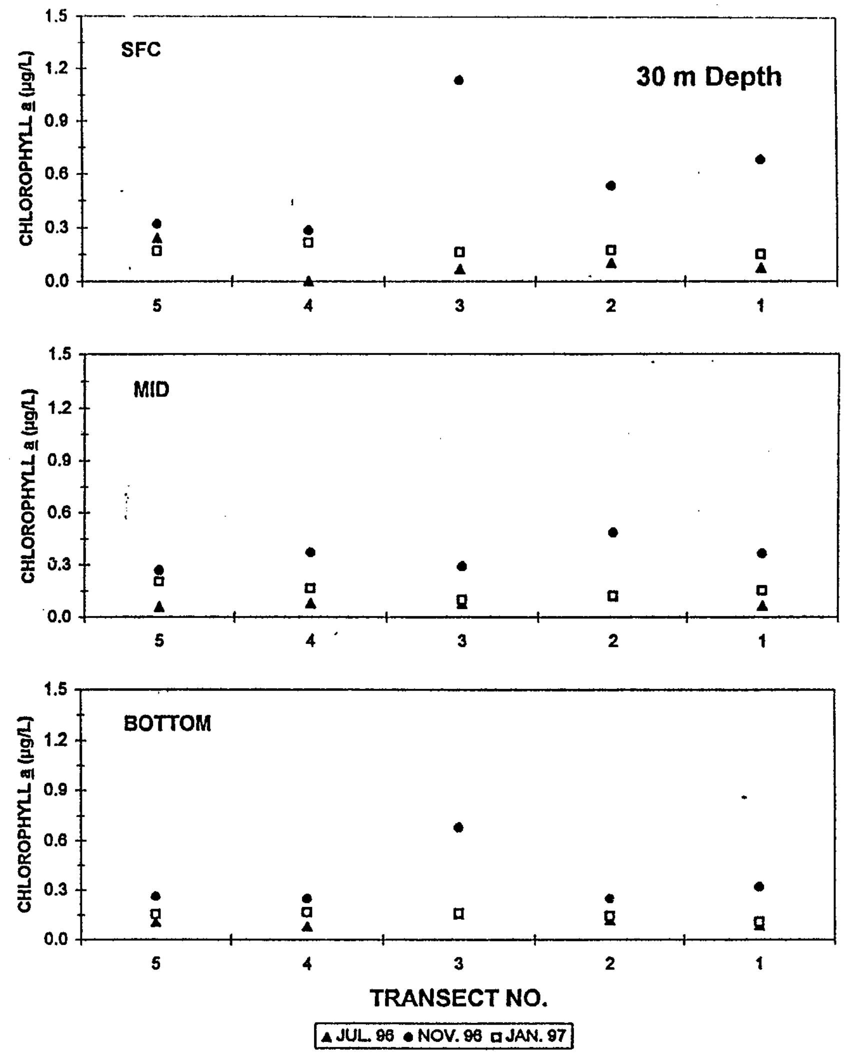


FIGURE 44. Scatter plots showing measurements of chlorophyll a in samples collected at the 30m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

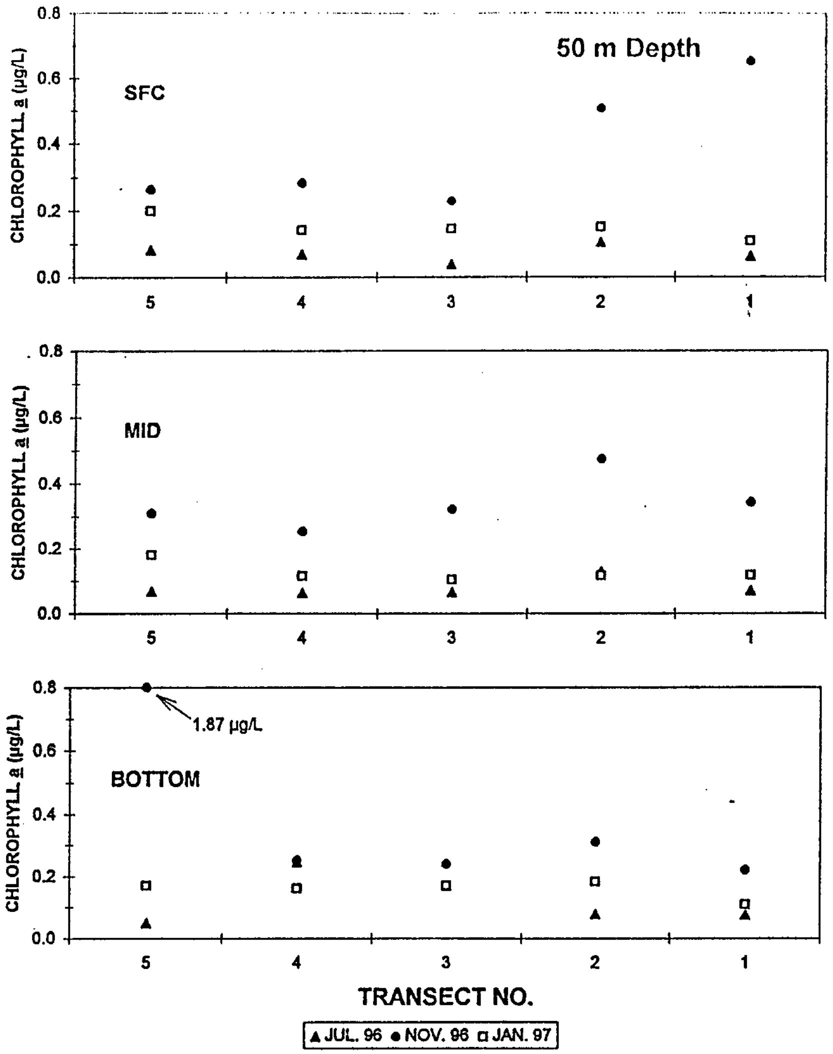


FIGURE 45. Scatter plots showing measurements of chlorophyll a in samples collected at the 50m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension.. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

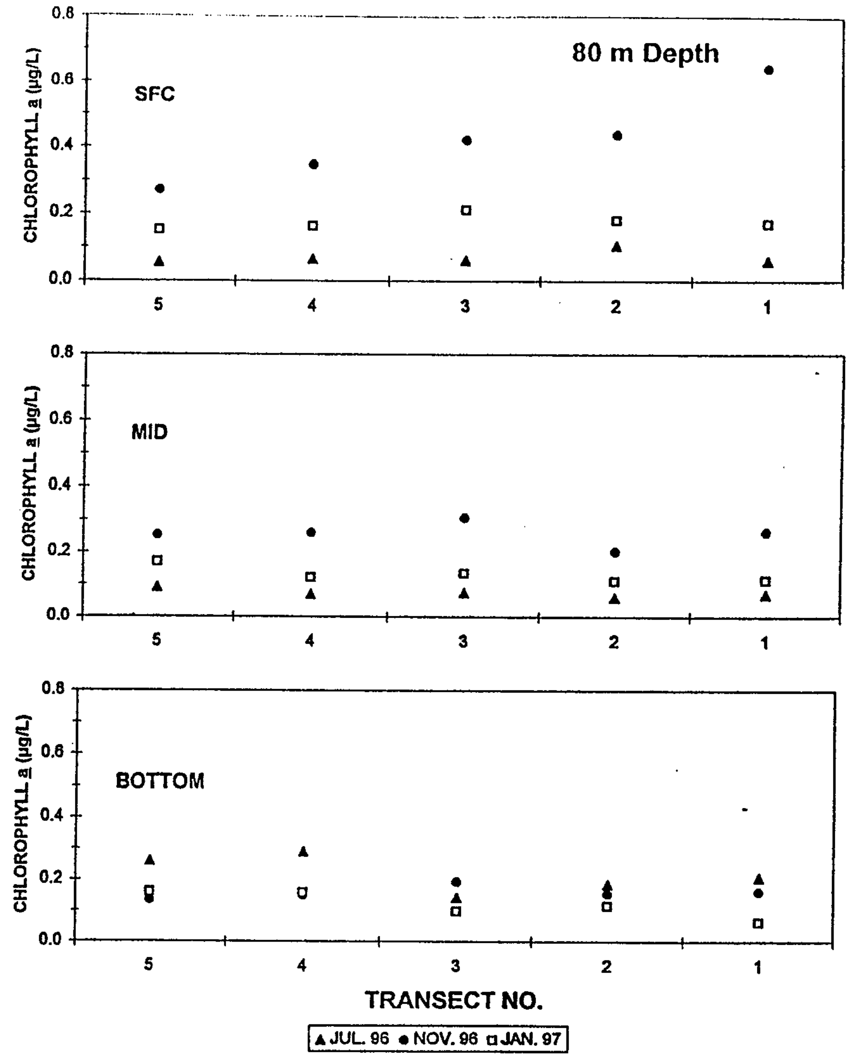


FIGURE 46. Scatter plots showing measurements of chlorophyll a in samples collected at the 80m contour (bottom depth) along five transect sites on three survey dates in the vicinity of the Fort Kamehameha sewage outfall extension. Transect numbers are arranged in an approximate West (#5) to East (#1) orientation. For transect and station locations, see Figure 1.

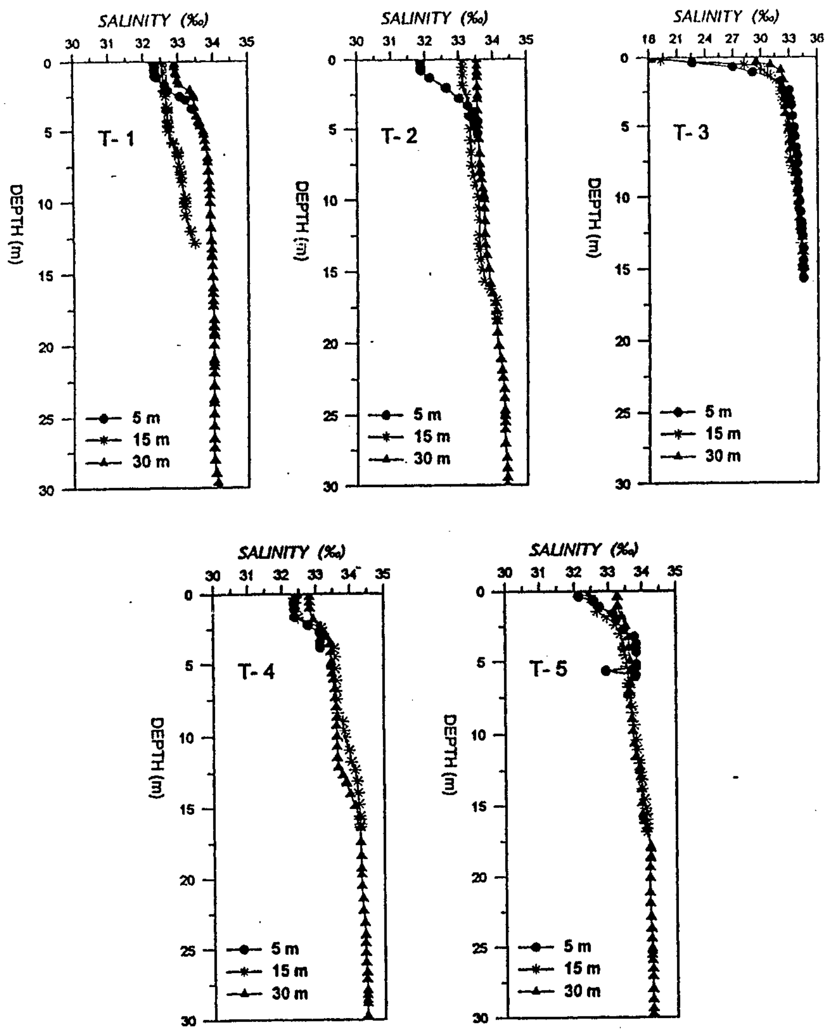


FIGURE 47. Vertical profiles of salinity (in ppt) measured at 3 stations (5m, 15m, and 30m depth contours) along 5 transects located in the vicinity of the Fort Kamehameha sewage outfall extension. Profiles were recorded on November 16, 1996. Note X-axis scale change for T-3 profile. For station locations, see Figure 1.

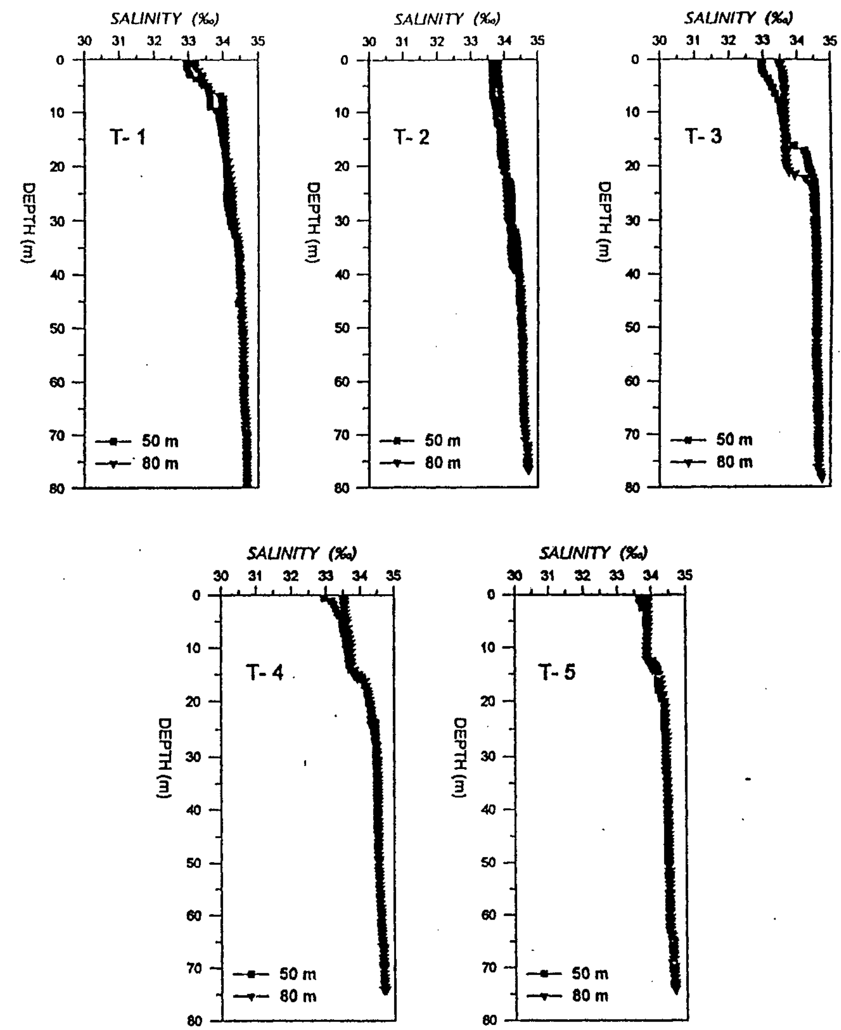


FIGURE 48. Vertical profiles of salinity (in ppt) measured at 2 stations (50m and 80m depth contours) along 5 transects located in the vicinity of the Fort Kamehameha sewage outfall extension. Profiles were recorded on November 16, 1996. For station locations, see Figure 1.

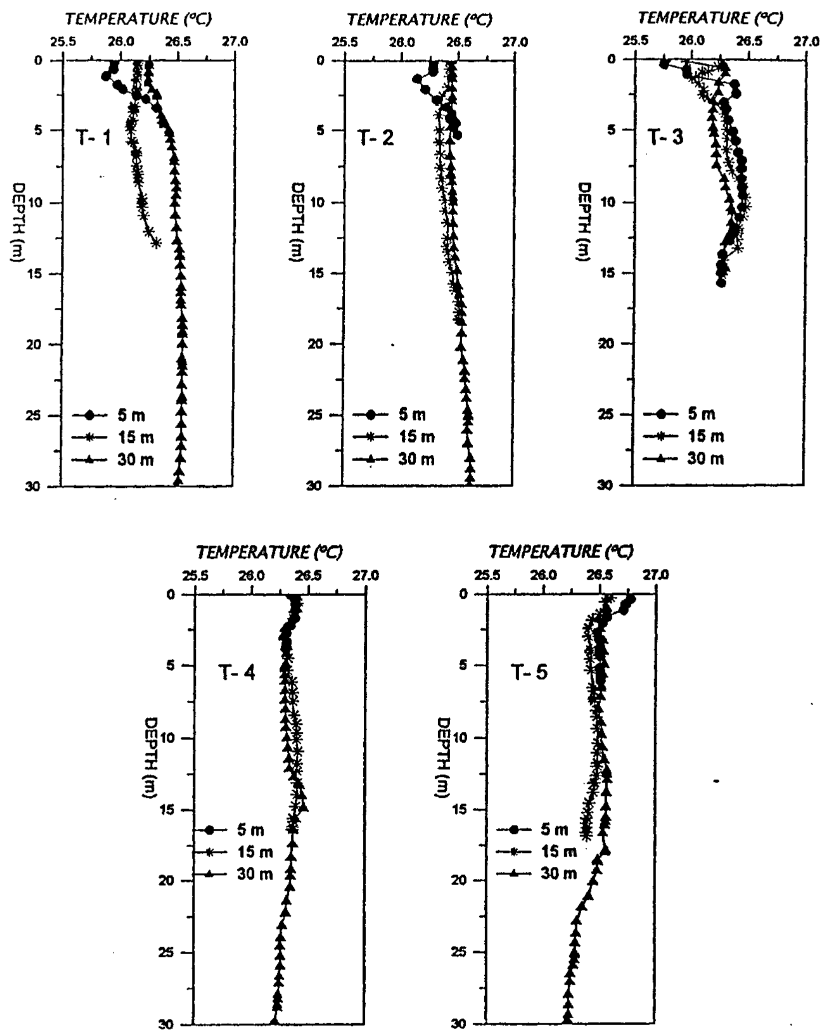


FIGURE 49. Vertical profiles of temperature measured at 3 stations (5m, 15m, and 30m depth contours) along 5 transects located in the vicinity of the Fort Kamehameha sewage outfall extension. Profiles were recorded on November 16, 1996. For station locations, see Figure 1.

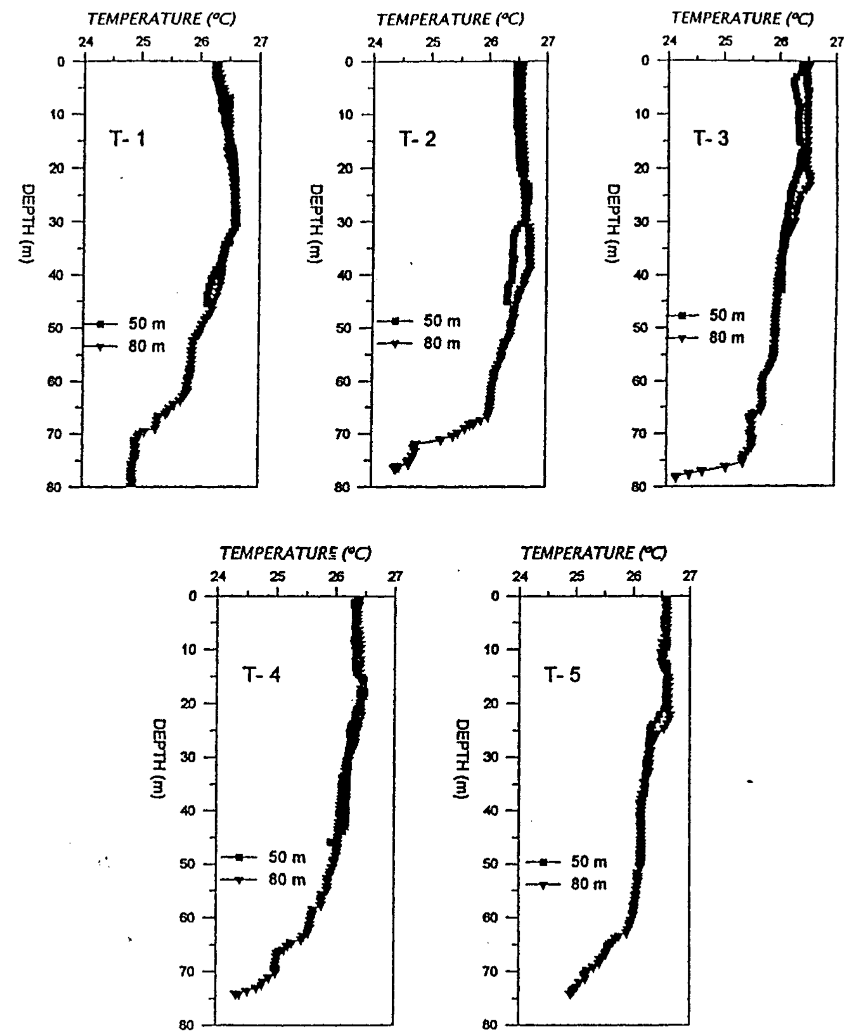


FIGURE 50. Vertical profiles of temperature measured at 2 stations (50m and 80m depth contours) along 5 transects located in the vicinity of the Fort Kamehameha sewage outfall extension. Profiles were recorded on November 16, 1996. For station locations, see Figure 1.

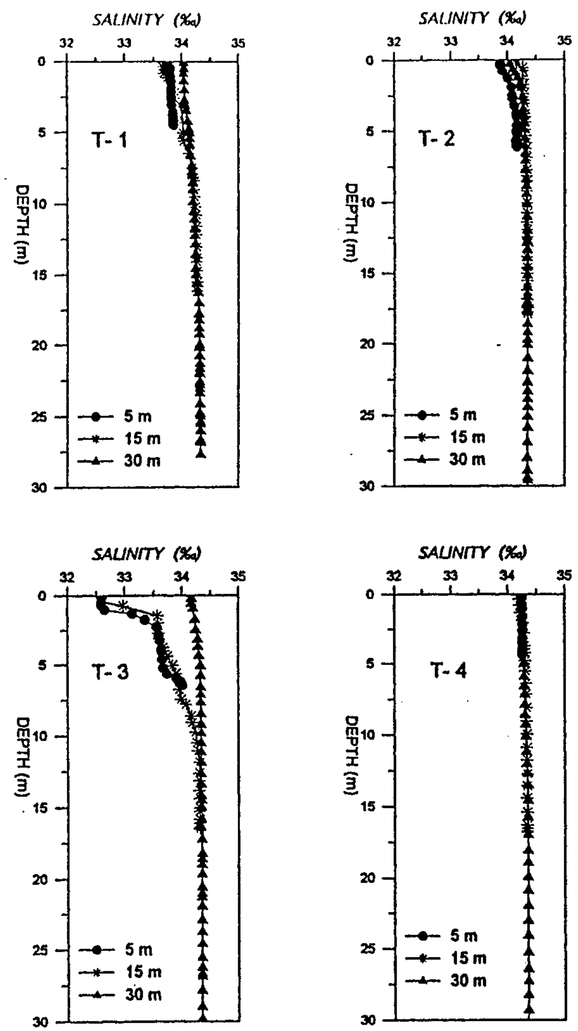


FIGURE 51. Vertical profiles of salinity (in ppt) measured at 3 stations (5m, 15m, and 30m depth contours) along 4 transects located in the vicinity of the Fort Kamehameha sewage outfall extension. Profiles were recorded on January 20, 1997. For station locations, see Figure 1.

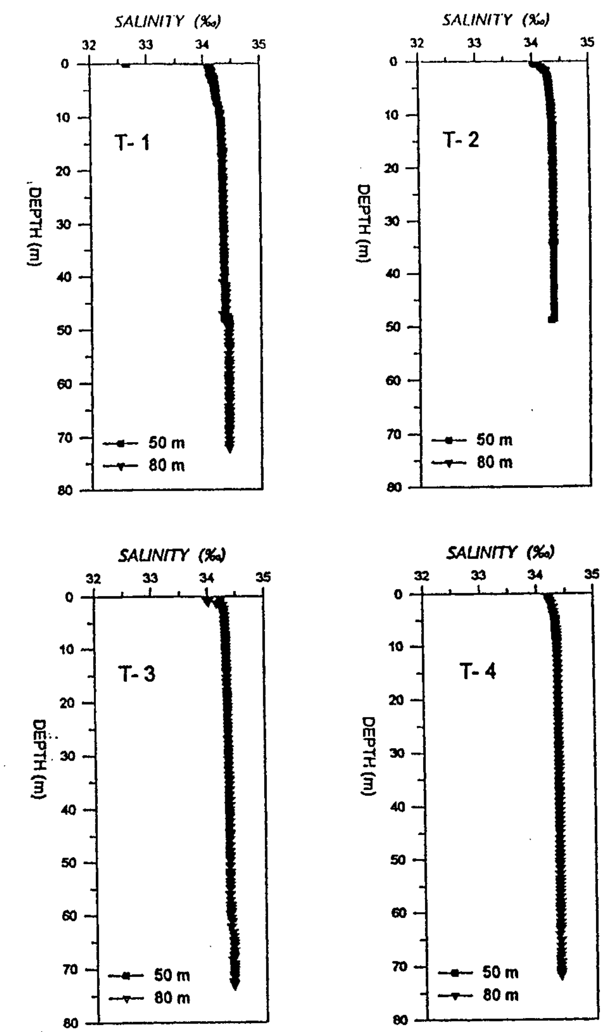


FIGURE 52. Vertical profiles of salinity (in ppt) measured at 2 stations (50m and 80m depth contours) along 4 transects located in the vicinity of the Fort Kamehameha sewage outfall extension. Profiles were recorded on January 20, 1997. For station locations, see Figure 1.

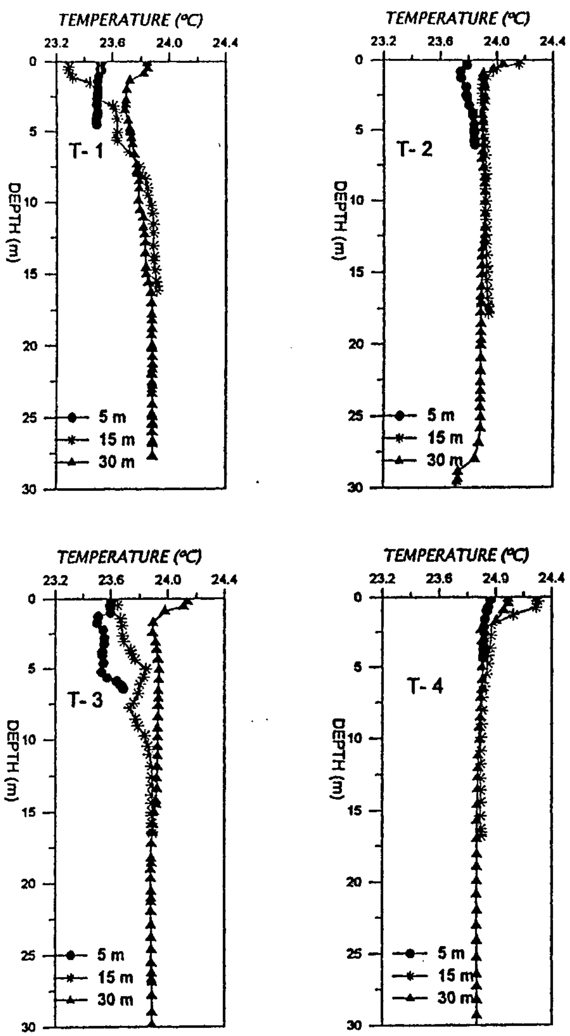


FIGURE 53. Vertical profiles of temperature measured at 3 stations (5m, 15m, and 30m depth contours) along 4 transects located in the vicinity of the Fort Kamehameha sewage outfall extension. Profiles were recorded on January 20, 1997. For station locations, see Figure 1.

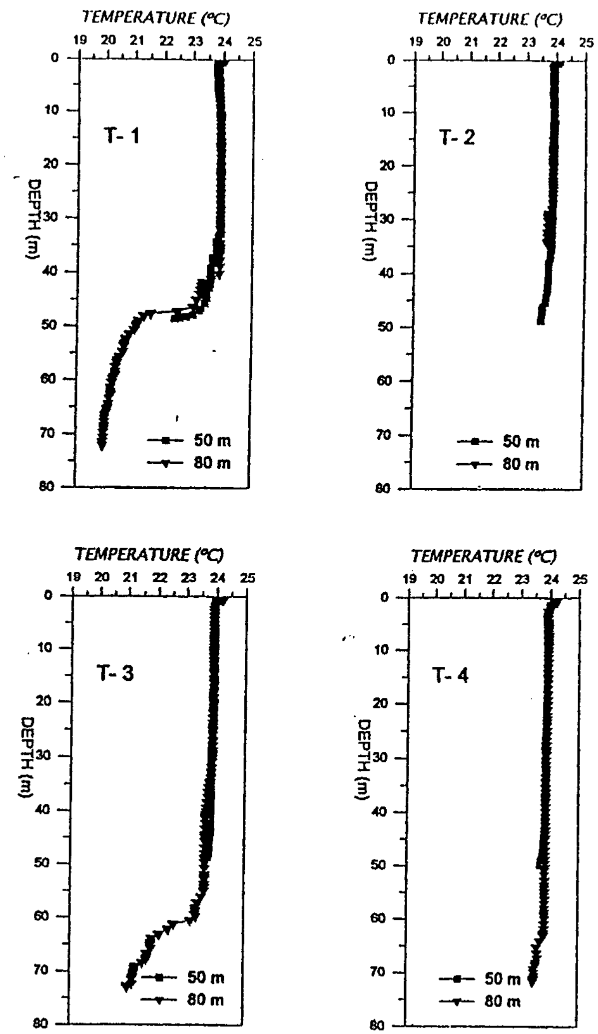


FIGURE 54. Vertical profiles of temperature measured at 2 stations (50m and 80m depth contours) along 4 transects located in the vicinity of the Fort Kamehameha sewage outfall extension. Profiles were recorded on January 20, 1997. For station locations, see Figure 1.

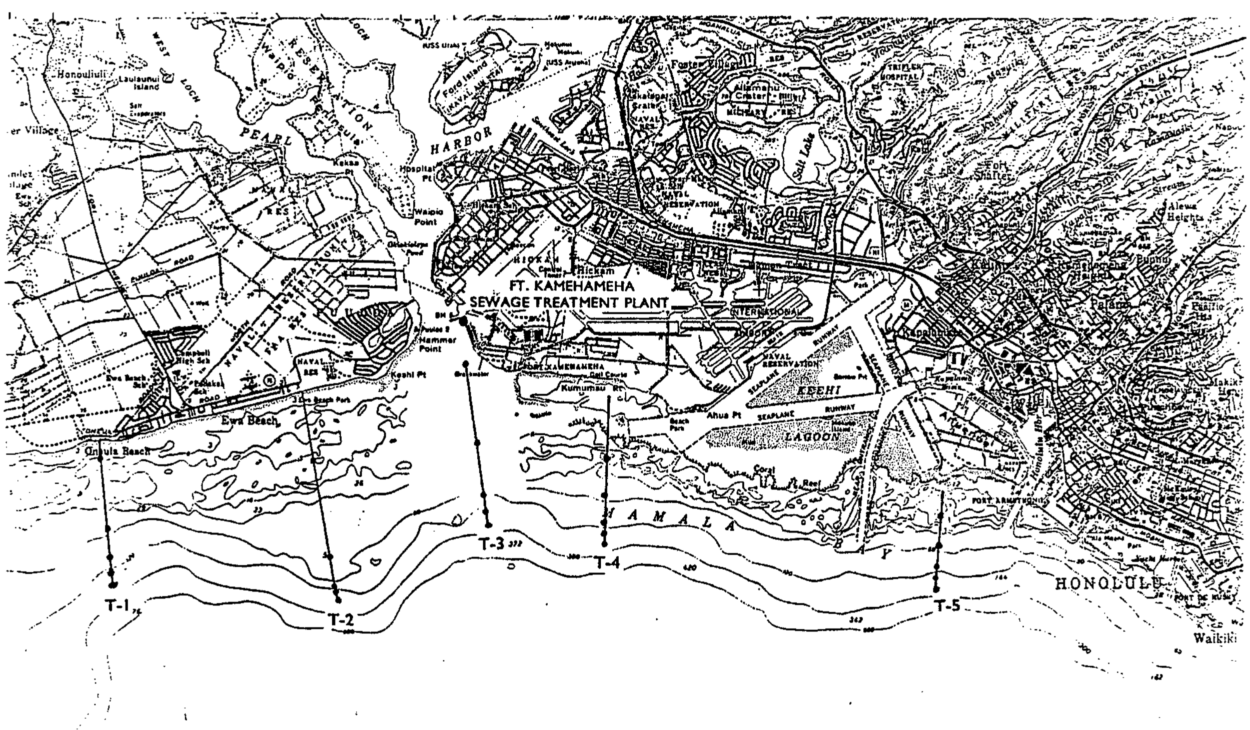


FIGURE 1. Map of portion of south coast of Oahu showing location of Ft. Kamehameha Sewage Treatment Plant and locations of 5 sampling transects. Filled circles on transects are approximate locations of sampling stations.

Appendix XIII

XIII-a—Effluent Sample Results;
XIII-b—Fish Sample Results

Appendix XIII-a

Effluent Sample Results

ASSOCIATED LABORATORIES
806 North Batavia · Orange, California 92868 · 714/771-6900
FAX 714/538-1209

CLIENT
Marine Research Consultants
Attn: Steve Dollar
4467 Sierra Dr.
Honolulu, Hi. 96816

LAB NO. LR26827
REPORTED 09/04/98

SAMPLE Water
RECEIVED 08/28/98

IDENTIFICATION F7 Kam Composite
Date Collected 08/25-08/26/98
BASED ON SAMPLE As Submitted

TCLP-INORGANICS

	Limits (mg/l)	Method	Date/Analyst	Results (mg/l)
Arsenic	5.0	EPA 7060	09/01 MT	ND< 0.02
Barium	100.0	EPA 6010	09/01 MT	0.03
Cadmium	1.0	EPA 6010	09/01 MT	0.003
Chromium	5.0	EPA 6010	09/01 MT	0.03
Lead	5.0	EPA 7421	09/01 MT	ND< 0.1
Mercury	0.2	EPA 7470	09/05 NS	ND< 0.004
Selenium	1.0	EPA 7740	09/01 MT	ND< 0.02
Silver	5.0	EPA 6010	09/01 MT	ND< 0.02

TCLP-VOLATILES

	Limits (mg/l)	Method	Date/Analyst	Results (mg/l)
Benzene	0.5	EPA 8240	09/02 AS	ND< 0.01
Carbon Tetrachloride	0.5	EPA 8240	09/02 AS	0.007
Chlorobenzene	100.0	EPA 8240	09/02 AS	0.063
Chloroform	6.0	EPA 8240	09/02 AS	ND< 0.01
1,2-Dichloroethane	0.5	EPA 8240	09/02 AS	ND< 0.01
1,1-Dichloroethylene	0.7	EPA 8240	09/02 AS	ND< 0.01
Methyl-ethyl-ketone	200.0	EPA 8240	09/02 AS	ND< 0.01
Tetrachloroethylene	0.7	EPA 8240	09/02 AS	ND< 0.01
Trichloroethylene	0.5	EPA 8240	09/02 AS	ND< 0.01
Vinyl Chloride	0.25	EPA 8240	09/02 AS	ND< 0.06

Cont'd on Next page

TESTING & CONSULTING
Chemical ·
Microbiological ·
Environmental ·

C-1 10M

Client: Marine Research Consultants
Lab No: LR26827

TCLP-PESTICIDES

	Limits (mg/l)	Method	Date/Analyst	Results (mg/l)
Chlordane	0.03	EPA 8080	09/04 LS	ND< 0.01
Endrin	0.02	EPA 8080	09/04 LS	ND< 0.002
Heptachlor	0.008	EPA 8080	09/04 LS	ND< 0.001
Heptachlor Epoxide	0.008	EPA 8080	09/04 LS	ND< 0.001
Lindane	0.4	EPA 8080	09/04 LS	ND< 0.05
Methoxychlor	10.0	EPA 8080	09/04 LS	ND< 0.01
Toxaphene	0.5	EPA 8080	09/04 LS	ND< 0.0001
PCB's	---	EPA 8080	09/04 LS	ND< 0.05
DDT	0.05	EPA 8080	09/04 LS	ND< 0.05
Dieldrin	0.05	EPA 8080	09/04 LS	ND< 0.06
Endosulfan I	0.06	EPA 8080	09/04 LS	ND< 0.05
Endosulfan II	0.05	EPA 8080		

TCLP-HERBICIDES

	Limits (mg/l)	Method	Date/Analyst	Results (mg/l)
2,4-D	10.0	EPA 8150	09/04 LS	ND< 0.05
2,4,5-TP (Silvex)	1.0	EPA 8150	09/04 LS	ND< 0.01

Constituent	Date/Analyst	EPA Method	Method Detection Limit	Results
Copper	09/01 MT	200.7	0.002	0.014 mg/l
Iron	09/01 MT	200.7	0.010	ND mg/l
Nickel	09/01 MT	200.7	0.005	ND mg/l
Zinc	09/01 MT	200.7	0.002	0.026 mg/l
Cyanide	09/02 JA	335.2	0.01	ND mg/l

ASSOCIATED LABORATORIES, by:

Robert A. Webber
Vice President

RAW/gk

Rev. 09/24/98 RAW/gk

NOTE: Unless notified in writing, all samples will be discarded by appropriate disposal protocol 30 days from date reported.

ASSOCIATED LABORATORIES

806 North Batavia - Orange, California 92868 - 714/771-6900
FAX 714/538-1209

CLIENT

Marine Research Consultants
Attn: Steve Dollar
4467 Sierra Dr.
Honolulu, Hi. 96816

LAB NO. LR26827-02
REPORTED 09/04/98

SAMPLE Water
RECEIVED 08/28/98

IDENTIFICATION F7 Kam Composite
BASED ON SAMPLE Date Collected 08/26-08/27/98
As Submitted

TCLP-INORGANICS

	Limits (mg/l)	Method	Date/Analyst	Results (mg/l)
Arsenic	5.0	EPA 7060	09/01 MT	ND< 0.02
Barium	100.0	EPA 6010	09/01 MT	0.023
Cadmium	1.0	EPA 6010	09/01 MT	ND< 0.02
Chromium	5.0	EPA 6010	09/01 MT	0.008
Lead	5.0	EPA 7421	09/01 MT	ND< 0.1
Mercury	0.2	EPA 7470	09/02 NS	ND< 0.004
Selenium	1.0	EPA 7740	09/01 MT	ND< 0.02
Silver	5.0	EPA 6010	09/01 MT	0.003

TCLP-VOLATILES

	Limits (mg/l)	Method	Date/Analyst	Results (mg/l)
Benzene	0.5	EPA 8240	09/02 AS	ND< 0.01
Carbon Tetrachloride	0.5	EPA 8240	09/02 AS	ND< 0.01
Chlorobenzene	100.0	EPA 8240	09/02 AS	ND< 0.01
Chloroform	6.0	EPA 8240	09/02 AS	ND< 0.01
1,2-Dichloroethane	0.5	EPA 8240	09/02 AS	ND< 0.01
1,1-Dichloroethylene	0.7	EPA 8240	09/02 AS	ND< 0.01
Methyl-ethyl-ketone	200.0	EPA 8240	09/02 AS	ND< 0.01
Tetrachloroethylene	0.7	EPA 8240	09/02 AS	ND< 0.01
Trichloroethylene	0.5	EPA 8240	09/02 AS	ND< 0.01
Vinyl Chloride	0.25	EPA 8240	09/02 AS	ND< 0.06

Cont'd on Next page

Client: Marine Research Consultants
Lab No: LR26827-02

TCLP-PESTICIDES

	Limits (mg/l)	Method	Date/Analyst	Results (mg/l)
Chlordane	0.03	EPA 8080	09/04 LS	ND< 0.01
Endrin	0.02	EPA 8080	09/04 LS	ND< 0.002
Heptachlor	0.008	EPA 8080	09/04 LS	ND< 0.001
Heptachlor Epoxide	0.008	EPA 8080	09/04 LS	ND< 0.001
Lindane	0.4	EPA 8080	09/04 LS	ND< 0.001
Methoxychlor	10.0	EPA 8080	09/04 LS	ND< 0.05
Toxaphene	0.5	EPA 8080	09/04 LS	ND< 0.01
PCB's	---	EPA 8080	09/04 LS	ND< 0.0001
DDT	0.05	EPA 8080	09/04 LS	ND< 0.05
Dieldrin	0.05	EPA 8080	09/04 LS	ND< 0.05
Endosulfan I	0.06	EPA 8080	09/04 LS	ND< 0.06
Endosulfan II	0.05	EPA 8080	09/04 LS	ND< 0.05

TCLP-HERBICIDES

	Limits (mg/l)	Method	Date/Analyst	Results (mg/l)
2,4-D	10.0	EPA 8150	09/04 LS	ND< 0.05
2,4,5-TP (Silvex)	1.0	EPA 8150	09/04 LS	ND< 0.01

Constituent	Date/ Analyst	EPA Method	Method Detection Limit	Results
Copper	09/01 MT	200.7	0.002	0.014 mg/l
Iron	09/01 MT	200.7	0.010	ND mg/l
Nickel	09/01 MT	200.7	0.005	ND mg/l
Zinc	09/01 MT	200.7	0.002	0.022 mg/l
Cyanide	09/02 JA	335.2	0.01	ND mg/l

ASSOCIATED LABORATORIES, by:

Robert A. Webber
Vice President

RAW/gk

Rev. 09/24/98 RAW/gk

NOTE: Unless notified in writing, all samples will be discarded by appropriate disposal protocol 30 days from date reported.

Appendix XIII-b

Fish Sample Results

DATE: 4 September 1998

TO: Steve Dollar
Marine Research Consultants

FROM: Richard Brock

SUBJECT: Fish Specimens for Pesticide Analysis - Fort Kam

On 3 September we went to the receiving waters fronting the Fort Kam STP for the purpose of collecting fish specimens for tissue pesticide/heavy metal analysis. Because we could not find an top level carnivores (specifically moray eels), we collected specimens of three different species for these tissue analyses. These fishes were collected from along the Pearl Harbor entrance channel around the concrete dolphin bearing a red and white metal sign on it marking the east side of the channel. This dolphin is approximately 250m seaward of the STP discharge along the channel edge. These fishes were collected within 50m of the dolphin. The control site is located offshore of Ala Moana Park in a similar depth (6 to 8m) and fishes were taken within an approximately 50 square meter area. These locations are given on the two accompanying maps. The fishes captured and their standard lengths are given below:

Sample No. Species	Number Caught	Standard Lengths in mm
Experimental Pearl Harbor Site:		
Sample Jar 1 - manini (*Acanthurus triostegus*)	1	156
Sample Jar 2 - mamo (*Abudefduf abdominalis*)	3	130, 137, 130
Sample Jar 3 - kole (*Ctenochaetus strigosus*)	3	114, 121, 108
Control Site (Ala Moana):		
Sample Jar 4 - manini (*Acanthurus triostegus*)	3	133, 98, 95
Sample Jar 5 - mamo (*Abudefduf abdominalis*)	3	117, 108, 108
Sample Jar 6 - kole (*Ctenochaetus strigosus*)	3	105, 102, 108

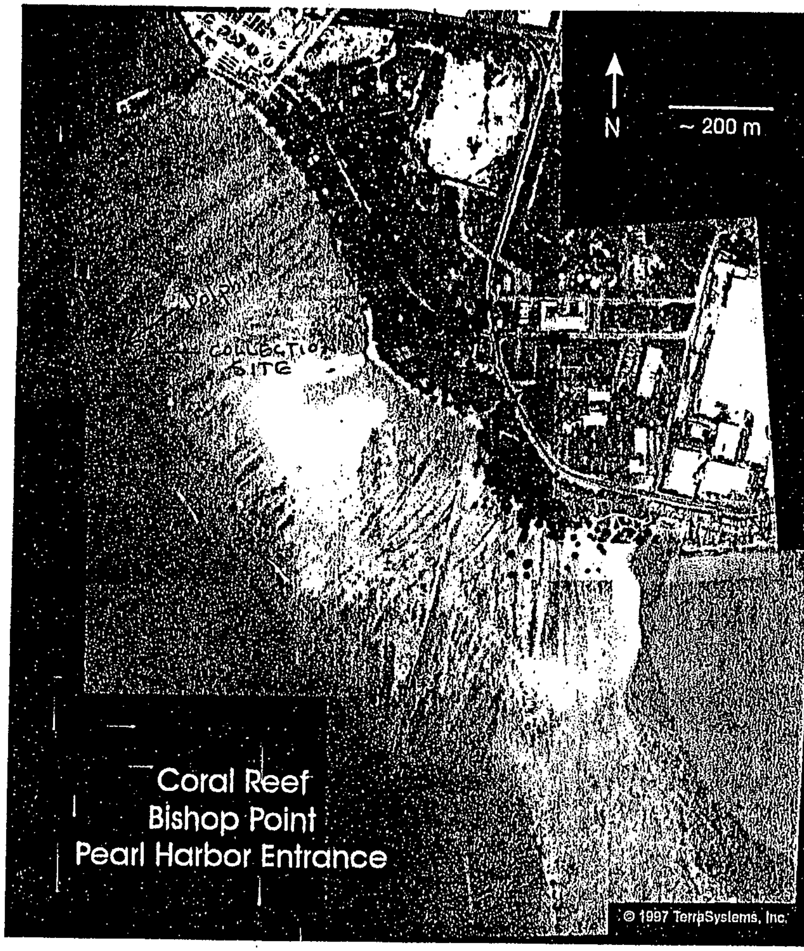
Unfortunately, only one manini could be captured at the experimental site but since it was relatively large, it provided ample material for analysis. In all cases, the fishes were carefully cut

into pieces and the gut as well as head material removed. Only muscle tissue with skin attached was used in making the composite samples. Each composite was made up from the three individuals of each species captured from each of the two areas. Tissue samples were removed, lightly rinsed and placed in precleaned (acetone rinsed) amber jars fitted with teflon-lined lids which are standard containers for pesticide analyses. Samples were frozen until time of analysis.

Each of the three species is in a differing trophic category. Kole feed primarily on detritus from the bottom (their gut contents often contain a high percentage of sand/carbonate material), mamo is a planktivore, feeding on crustaceans and other suspended material in the watercolumn, and manini are herbivorous, feeding on fine filamentous algae that grows attached to reef surfaces. Thus the sampled specimens cover a relatively broad trophic spectrum and are representative of the fishes found in the vicinity of the Fort Kam STP outfall.

Any questions, please do not hesitate calling.

encl.


N
~ 200 m
COLLECTION SITE
Coral Reef
Bishop Point
Pearl Harbor Entrance
© 1997 TerraSystems, Inc.


CONTROL SAMPLE SITE
HONOLULU
BAY
Kewalo Basin
ALA MOANA PARK
AINA MOANA STATE RECREATION AREA
FORT DE RUSSY MILITARY RES
WAIKIKI BEACH
Waikiki
ALA WAI CANAL
ALA WAI GOLF COURSE
Moiliili
Kapahulu
KAPIOLANI PARK
Kapua Entrance
UNIVERSITY OF HAWAII

ASSOCIATED LABORATORIES
806 North Batavia - Orange, California 92868 - 714/771-6900
FAX 714/538-1209

CLIENT Marine Research Consultants (5188)
ATTN: Steven Dollar
4467 Sierra Dr.
Honolulu, HI 96816

LAB REQUEST 27232

REPORTED 9/24/98
RECEIVED 9/9/98

PROJECT F7 KAM WWTP Extension

SUBMITTER Client

COMMENTS

This laboratory request covers the following listed samples which were analyzed for the parameters indicated on the attached Analytical Result Report. All analyses were conducted using the appropriate methods as indicated on the report. This cover letter is an integral part of the final report.

Order No.	Client Sample Identification
82845	Jar 1
82846	Jar 2
82847	Jar 3
82848	Jar 4
82849	Jar 5
82850	Jar 6

Thank you for the opportunity to be of service to your company. Please feel free to call if there are any questions regarding this report or if we can be of further service.

ASSOCIATED LABORATORIES by,

Robert A. Webber
Vice President

NOTE: Unless notified in writing, all samples will be discarded by appropriate disposal protocol 30 days from date reported.

TESTING & CONSULTING
Chemical
Microbiological
Environmental

Matrix: SOLID
Date Sampled: 9/3/98
Time Sampled:
Sampled By:

Client Sample ID: Jar 1
Sample Description: Pearl Harbor

Analyte	Result	DF	DLR	Units	Date/Analyst
245.5 Mercury in Solids by Manual Cold Vapor					
Mercury	0.40	1	0.02	mg/Kg	9/23/98 NK
335.2 Total Cyanide					
Cyanide	ND	1	0.5	mg/Kg	9/22/98 BS
6010 ICP Metals - Solid/Liquid					
Antimony	ND	1	1.42	mg/Kg	9/22/98 MT
Arsenic	ND	1	0.20	mg/Kg	9/22/98 MT
Beryllium	ND	1	0.10	mg/Kg	9/22/98 MT
Cadmium	ND	1	0.15	mg/Kg	9/22/98 MT
Chromium	ND	1	0.17	mg/Kg	9/22/98 MT
Copper	3.51	1	0.11	mg/Kg	9/22/98 MT
Lead	ND	1	0.23	mg/Kg	9/22/98 MT
Nickel	ND	1	0.20	mg/Kg	9/22/98 MT
Selenium	ND	1	0.4	mg/Kg	9/22/98 MT
Silver	ND	1	0.50	mg/Kg	9/22/98 MT
Thallium	ND	1	0.4	mg/Kg	9/22/98 MT
Zinc	3.95	1	0.30	mg/Kg	9/22/98 MT
8080 - Chlorinated Pesticides and PCB's					
Aldrin	ND	1	0.002	mg/Kg	9/23/98 LS
Alpha BHC	ND	1	0.002	mg/Kg	9/23/98 LS
Beta BHC	ND	1	0.003	mg/Kg	9/23/98 LS
Chlordane	ND	1	0.008	mg/Kg	9/23/98 LS
DDD	ND	1	0.004	mg/Kg	9/23/98 LS
DDE	ND	1	0.003	mg/Kg	9/23/98 LS
DDT	ND	1	0.003	mg/Kg	9/23/98 LS
Delta BHC	ND	1	0.005	mg/Kg	9/23/98 LS
Dieldrin	ND	1	0.003	mg/Kg	9/23/98 LS
Endosulfan I	ND	1	0.004	mg/Kg	9/23/98 LS
Endosulfan II	ND	1	0.003	mg/Kg	9/23/98 LS
Endosulfan sulfate	ND	1	0.003	mg/Kg	9/23/98 LS
Endrin	ND	1	0.004	mg/Kg	9/23/98 LS
Endrin aldehyde	ND	1	0.004	mg/Kg	9/23/98 LS
Gamma BHC (Lindane)	ND	1	0.011	mg/Kg	9/23/98 LS
Heptachlor	ND	1	0.002	mg/Kg	9/23/98 LS

DLR = Detection limit for reporting purposes, ND = Not Detected below indicated detection limit, DF = Dilution Factor

Order #: 8-845
Matrix: SOLID
Date Sampled: 9/3/98
Time Sampled:
Sampled By:

Client Sample ID: Jar 1
Sample Description: Pearl Harbor

Analyte	Result	DF	DLR	Units	Date/Analyst
8080 - Chlorinated Pesticides and PCB's					
Heptachlor epoxide	ND	1	0.003	mg/Kg	9/23/98 LS
Kepone	ND	1	0.01	mg/Kg	9/23/98 LS
Methoxychlor	ND	1	0.025	mg/Kg	9/23/98 LS
Mirex	ND	1	0.012	mg/Kg	9/23/98 LS
PCB-1016	ND	1	0.033	mg/Kg	9/23/98 LS
PCB-1221	ND	1	0.05	mg/Kg	9/23/98 LS
PCB-1232	ND	1	0.04	mg/Kg	9/23/98 LS
PCB-1242	ND	1	0.02	mg/Kg	9/23/98 LS
PCB-1248	ND	1	0.08	mg/Kg	9/23/98 LS
PCB-1254	ND	1	0.011	mg/Kg	9/23/98 LS
PCB-1260	ND	1	0.025	mg/Kg	9/23/98 LS
Toxaphene	ND	1	0.24	mg/Kg	9/23/98 LS

DLR = Detection limit for reporting purposes, ND = Not Detected below indicated detection limit, DF = Dilution Factor

Matrix: SOLID
Client Sample ID: Jar 2
Date Sampled: 9/3/98
Sample Description: Pearl Harbor
Time Sampled:
Sampled By:

Analyte	Result	DF	DLR	Units	Date/Analyst
245.5 Mercury in Solids by Manual Cold Vapor					
Mercury	0.04	1	0.02	mg/Kg	9/23/98 NK
335.2 Total Cyanide					
Cyanide	ND	1	0.5	mg/Kg	9/22/98 BS
6010 ICP Metals - Solid/Liquid					
Antimony	ND	1	1.42	mg/Kg	9/21/98 MT
Arsenic	4.56	1	0.20	mg/Kg	9/21/98 MT
Beryllium	ND	1	0.10	mg/Kg	9/21/98 MT
Cadmium	ND	1	0.15	mg/Kg	9/21/98 MT
Chromium	ND	1	0.17	mg/Kg	9/21/98 MT
Copper	1.01	1	0.11	mg/Kg	9/21/98 MT
Lead	ND	1	0.40	mg/Kg	9/21/98 MT
Nickel	ND	1	0.20	mg/Kg	9/21/98 MT
Selenium	0.563	1	0.27	mg/Kg	9/21/98 MT
Silver	ND	1	0.50	mg/Kg	9/21/98 MT
Thallium	ND	1	0.04	mg/Kg	9/21/98 MT
Zinc	7.63	1	0.30	mg/Kg	9/21/98 MT
8080 - Chlorinated Pesticides and PCB's					
Aldrin	ND	1	0.002	mg/Kg	9/23/98 LS
Alpha BHC	ND	1	0.002	mg/Kg	9/23/98 LS
Beta BHC	ND	1	0.003	mg/Kg	9/23/98 LS
Chlordane	ND	1	0.008	mg/Kg	9/23/98 LS
DDD	ND	1	0.004	mg/Kg	9/23/98 LS
DDE	ND	1	0.003	mg/Kg	9/23/98 LS
DDT	ND	1	0.003	mg/Kg	9/23/98 LS
Delta BHC	ND	1	0.005	mg/Kg	9/23/98 LS
Dieldrin	ND	1	0.003	mg/Kg	9/23/98 LS
Endosulfan I	ND	1	0.004	mg/Kg	9/23/98 LS
Endosulfan II	ND	1	0.003	mg/Kg	9/23/98 LS
Endosulfan sulfate	ND	1	0.003	mg/Kg	9/23/98 LS
Endrin	ND	1	0.004	mg/Kg	9/23/98 LS
Endrin aldehyde	ND	1	0.004	mg/Kg	9/23/98 LS
Gamma BHC (Lindane)	ND	1	0.011	mg/Kg	9/23/98 LS
Heptachlor	ND	1	0.002	mg/Kg	9/23/98 LS

DLR = Detection limit for reporting purposes, ND = Not Detected below indicated detection limit, DF = Dilution Factor

Matrix: SOLID
Client Sample ID: Jar 2
Date Sampled: 9/3/98
Sample Description: Pearl Harbor
Time Sampled:
Sampled By:

Analyte	Result	DF	DLR	Units	Date/Analyst
8080 - Chlorinated Pesticides and PCB's					
Heptachlor epoxide	ND	1	0.003	mg/Kg	9/23/98 LS
Kepone	ND	1	0.01	mg/Kg	9/23/98 LS
Methoxychlor	ND	1	0.025	mg/Kg	9/23/98 LS
Mirex	ND	1	0.012	mg/Kg	9/23/98 LS
PCB-1016	ND	1	0.033	mg/Kg	9/23/98 LS
PCB-1221	ND	1	0.05	mg/Kg	9/23/98 LS
PCB-1232	ND	1	0.04	mg/Kg	9/23/98 LS
PCB-1242	ND	1	0.02	mg/Kg	9/23/98 LS
PCB-1248	ND	1	0.08	mg/Kg	9/23/98 LS
PCB-1254	ND	1	0.011	mg/Kg	9/23/98 LS
PCB-1260	ND	1	0.025	mg/Kg	9/23/98 LS
Toxaphene	ND	1	0.24	mg/Kg	9/23/98 LS

DLR = Detection limit for reporting purposes, ND = Not Detected below indicated detection limit, DF = Dilution Factor

Order #:
Matrix: SOLID
Date Sampled: 9/ 3/98
Time Sampled:
Sampled By:
Client Sample ID: Jar 3
Sample Description: Pearl Harbor

Analyte	Result	DF	DLR	Units	Date/Analyst	
245.5 Mercury in Solids by Manual Cold Vapor						
Mercury	ND	1	0.02	mg/Kg	9/23/98	NK
335.2 Total Cyanide						
Cyanide	ND	1	0.5	mg/Kg	9/22/98	BS
6010 ICP Metals - Solid/Liquid						
Antimony	2.97	1	1.42	mg/Kg	9/22/98	MT
Arsenic	ND	1	0.40	mg/Kg	9/22/98	MT
Beryllium	ND	1	0.10	mg/Kg	9/22/98	MT
Cadmium	ND	1	0.15	mg/Kg	9/22/98	MT
Chromium	ND	1	0.17	mg/Kg	9/22/98	MT
Copper	2.43	1	0.11	mg/Kg	9/22/98	MT
Lead	ND	1	0.40	mg/Kg	9/22/98	MT
Nickel	0.423	1	0.20	mg/Kg	9/22/98	MT
Selenium	ND	1	0.40	mg/Kg	9/22/98	MT
Silver	ND	1	0.50	mg/Kg	9/22/98	MT
Thallium	ND	1	0.40	mg/Kg	9/22/98	MT
Zinc	3.50	1	0.30	mg/Kg	9/22/98	MT
8080 - Chlorinated Pesticides and PCB's						
Aldrin	ND	1	0.002	mg/Kg	9/23/98	LS
Alpha BHC	ND	1	0.002	mg/Kg	9/23/98	LS
Beta BHC	ND	1	0.003	mg/Kg	9/23/98	LS
Chlordane	ND	1	0.008	mg/Kg	9/23/98	LS
DDD	ND	1	0.004	mg/Kg	9/23/98	LS
DDE	ND	1	0.003	mg/Kg	9/23/98	LS
DDT	ND	1	0.003	mg/Kg	9/23/98	LS
Delta BHC	ND	1	0.005	mg/Kg	9/23/98	LS
Dieldrin	ND	1	0.003	mg/Kg	9/23/98	LS
Endosulfan I	ND	1	0.004	mg/Kg	9/23/98	LS
Endosulfan II	ND	1	0.003	mg/Kg	9/23/98	LS
Endosulfan sulfate	ND	1	0.003	mg/Kg	9/23/98	LS
Endrin	ND	1	0.004	mg/Kg	9/23/98	LS
Endrin aldehyde	ND	1	0.004	mg/Kg	9/23/98	LS
Gamma BHC (Lindane)	ND	1	0.011	mg/Kg	9/23/98	LS
Heptachlor	ND	1	0.002	mg/Kg	9/23/98	LS

DLR = Detection limit for reporting purposes, ND = Not Detected below indicated detection limit, DF = Dilution Factor

Order #:
Matrix: SOLID
Date Sampled: 9/ 3/98
Time Sampled:
Sampled By:
Client Sample ID: Jar 3
Sample Description: Pearl Harbor

Analyte	Result	DF	DLR	Units	Date/Analyst	
8080 - Chlorinated Pesticides and PCB's						
Heptachlor epoxide	ND	1	0.003	mg/Kg	9/23/98	LS
Kepone	ND	1	0.01	mg/Kg	9/23/98	LS
Methoxychlor	ND	1	0.025	mg/Kg	9/23/98	LS
Mirex	ND	1	0.012	mg/Kg	9/23/98	LS
PCB-1016	ND	1	0.033	mg/Kg	9/23/98	LS
PCB-1221	ND	1	0.05	mg/Kg	9/23/98	LS
PCB-1232	ND	1	0.04	mg/Kg	9/23/98	LS
PCB-1242	ND	1	0.02	mg/Kg	9/23/98	LS
PCB-1248	ND	1	0.08	mg/Kg	9/23/98	LS
PCB-1254	ND	1	0.011	mg/Kg	9/23/98	LS
PCB-1260	ND	1	0.025	mg/Kg	9/23/98	LS
Toxaphene	ND	1	0.24	mg/Kg	9/23/98	LS

DLR = Detection limit for reporting purposes, ND = Not Detected below indicated detection limit, DF = Dilution Factor

Order #:
Matrix: SOLID
Date Sampled: 9/3/98
Time Sampled:
Sampled By:
Client Sample ID: Jar 3
Sample Description: Pearl Harbor

Analyte	Result	DF	DLR	Units	Date/Analyst	
245.5 Mercury in Solids by Manual Cold Vapor						
Mercury	ND	1	0.02	mg/Kg	9/23/98	NK
335.2 Total Cyanide						
Cyanide	ND	1	0.5	mg/Kg	9/22/98	BS
6010 ICP Metals - Solid/Liquid						
Antimony	2.97	1	1.42	mg/Kg	9/22/98	MT
Arsenic	ND	1	0.40	mg/Kg	9/22/98	MT
Beryllium	ND	1	0.10	mg/Kg	9/22/98	MT
Cadmium	ND	1	0.15	mg/Kg	9/22/98	MT
Chromium	ND	1	0.17	mg/Kg	9/22/98	MT
Copper	2.43	1	0.11	mg/Kg	9/22/98	MT
Lead	ND	1	0.40	mg/Kg	9/22/98	MT
Nickel	0.423	1	0.20	mg/Kg	9/22/98	MT
Selenium	ND	1	0.40	mg/Kg	9/22/98	MT
Silver	ND	1	0.50	mg/Kg	9/22/98	MT
Thallium	ND	1	0.40	mg/Kg	9/22/98	MT
Zinc	3.50	1	0.30	mg/Kg	9/22/98	MT
8080 - Chlorinated Pesticides and PCB's						
Aldrin	ND	1	0.002	mg/Kg	9/23/98	LS
Alpha BHC	ND	1	0.002	mg/Kg	9/23/98	LS
Beta BHC	ND	1	0.003	mg/Kg	9/23/98	LS
Chlordane	ND	1	0.008	mg/Kg	9/23/98	LS
DDD	ND	1	0.004	mg/Kg	9/23/98	LS
DDE	ND	1	0.003	mg/Kg	9/23/98	LS
DDT	ND	1	0.003	mg/Kg	9/23/98	LS
Delta BHC	ND	1	0.005	mg/Kg	9/23/98	LS
Dieldrin	ND	1	0.003	mg/Kg	9/23/98	LS
Endosulfan I	ND	1	0.004	mg/Kg	9/23/98	LS
Endosulfan II	ND	1	0.003	mg/Kg	9/23/98	LS
Endosulfan sulfate	ND	1	0.003	mg/Kg	9/23/98	LS
Endrin	ND	1	0.004	mg/Kg	9/23/98	LS
Endrin aldehyde	ND	1	0.004	mg/Kg	9/23/98	LS
Gamma BHC (Lindane)	ND	1	0.011	mg/Kg	9/23/98	LS
Heptachlor	ND	1	0.002	mg/Kg	9/23/98	LS

DLR = Detection limit for reporting purposes, ND = Not Detected below indicated detection limit, DF = Dilution Factor

Order #:
Matrix: SOLID
Date Sampled: 9/3/98
Time Sampled:
Sampled By:
Client Sample ID: Jar 3
Sample Description: Pearl Harbor

Analyte	Result	DF	DLR	Units	Date/Analyst	
8080 - Chlorinated Pesticides and PCB's						
Heptachlor epoxide	ND	1	0.003	mg/Kg	9/23/98	LS
Kepone	ND	1	0.01	mg/Kg	9/23/98	LS
Methoxychlor	ND	1	0.025	mg/Kg	9/23/98	LS
Mirex	ND	1	0.012	mg/Kg	9/23/98	LS
PCB-1016	ND	1	0.033	mg/Kg	9/23/98	LS
PCB-1221	ND	1	0.05	mg/Kg	9/23/98	LS
PCB-1232	ND	1	0.04	mg/Kg	9/23/98	LS
PCB-1242	ND	1	0.02	mg/Kg	9/23/98	LS
PCB-1248	ND	1	0.08	mg/Kg	9/23/98	LS
PCB-1254	ND	1	0.011	mg/Kg	9/23/98	LS
PCB-1260	ND	1	0.025	mg/Kg	9/23/98	LS
Toxaphene	ND	1	0.24	mg/Kg	9/23/98	LS

DLR = Detection limit for reporting purposes, ND = Not Detected below indicated detection limit, DF = Dilution Factor

Matrix: SOLID
Date Sampled: 9/3/98
Time Sampled:
Sampled By:
Client Sample ID: Jar 4
Sample Description: Ala Moana

Analyte	Result	DF	DLR	Units	Date/Analyst	
245.5 Mercury in Solids by Manual Cold Vapor						
Mercury	0.14	1	0.12	mg/Kg	9/23/98	NK
335.2 Total Cyanide						
Cyanide	ND	1	0.5	mg/Kg	9/22/98	JA
6010 ICP Metals - Solid/Liquid						
Antimony	1.91	1	1.42	mg/Kg	9/22/98	MT
Arsenic	ND	1	0.40	mg/Kg	9/22/98	MT
Beryllium	ND	1	0.10	mg/Kg	9/22/98	MT
Cadmium	ND	1	0.15	mg/Kg	9/22/98	MT
Chromium	ND	1	0.17	mg/Kg	9/22/98	MT
Copper	1.45	1	0.11	mg/Kg	9/22/98	MT
Lead	ND	1	0.40	mg/Kg	9/22/98	MT
Nickel	ND	1	0.20	mg/Kg	9/22/98	MT
Selenium	ND	1	0.40	mg/Kg	9/22/98	MT
Silver	ND	1	0.50	mg/Kg	9/22/98	MT
Thallium	ND	1	0.40	mg/Kg	9/22/98	MT
Zinc	4.34	1	0.30	mg/Kg	9/22/98	MT
8080 - Chlorinated Pesticides and PCB's						
Aldrin	ND	1	0.002	mg/Kg	9/23/98	LS
Alpha BHC	ND	1	0.002	mg/Kg	9/23/98	LS
Beta BHC	ND	1	0.003	mg/Kg	9/23/98	LS
Chlordane	ND	1	0.008	mg/Kg	9/23/98	LS
DDD	ND	1	0.004	mg/Kg	9/23/98	LS
DDE	ND	1	0.003	mg/Kg	9/23/98	LS
DDT	ND	1	0.003	mg/Kg	9/23/98	LS
Delta BHC	ND	1	0.005	mg/Kg	9/23/98	LS
Dieldrin	ND	1	0.003	mg/Kg	9/23/98	LS
Endosulfan I	ND	1	0.004	mg/Kg	9/23/98	LS
Endosulfan II	ND	1	0.003	mg/Kg	9/23/98	LS
Endosulfan sulfate	ND	1	0.003	mg/Kg	9/23/98	LS
Endrin	ND	1	0.004	mg/Kg	9/23/98	LS
Endrin aldehyde	ND	1	0.004	mg/Kg	9/23/98	LS
Gamma BHC (Lindane)	ND	1	0.011	mg/Kg	9/23/98	LS
Heptachlor	ND	1	0.002	mg/Kg	9/23/98	LS

DLR = Detection limit for reporting purposes, ND = Not Detected below indicated detection limit, DF = Dilution Factor

Matrix: SOLID
Date Sampled: 9/3/98
Time Sampled:
Sampled By:
Client Sample ID: Jar 4
Sample Description: Ala Moana

Analyte	Result	DF	DLR	Units	Date/Analyst	
8080 - Chlorinated Pesticides and PCB's						
Heptachlor epoxide	ND	1	0.003	mg/Kg	9/23/98	LS
Kepone	ND	1	0.01	mg/Kg	9/23/98	LS
Methoxychlor	ND	1	0.025	mg/Kg	9/23/98	LS
Mirex	ND	1	0.012	mg/Kg	9/23/98	LS
PCB-1016	ND	1	0.033	mg/Kg	9/23/98	LS
PCB-1221	ND	1	0.05	mg/Kg	9/23/98	LS
PCB-1232	ND	1	0.04	mg/Kg	9/23/98	LS
PCB-1242	ND	1	0.02	mg/Kg	9/23/98	LS
PCB-1248	ND	1	0.08	mg/Kg	9/23/98	LS
PCB-1254	ND	1	0.011	mg/Kg	9/23/98	LS
PCB-1260	ND	1	0.025	mg/Kg	9/23/98	LS
Toxaphene	ND	1	0.24	mg/Kg	9/23/98	LS

DLR = Detection limit for reporting purposes. ND = Not Detected below indicated detection limit, DF = Dilution Factor

Matrix: SOLID
Date Sampled: 9/3/98
Time Sampled:
Sampled By:

Client Sample ID: Jar 5
Sample Description: Ala Moana

Analyte	Result	DF	DLR	Units	Date/Analyst
245.5 Mercury in Solids by Manual Cold Vapor					
Mercury	ND	1	0.02	mg/Kg	9/23/98 NK
335.2 Total Cyanide					
Cyanide	ND	1	0.5	mg/Kg	9/22/98 JA
6010 ICP Metals - Solid/Liquid					
Antimony	2.35	1	1.42	mg/Kg	9/22/98 MT
Arsenic	1.34	1	0.20	mg/Kg	9/22/98 MT
Beryllium	ND	1	0.10	mg/Kg	9/22/98 MT
Cadmium	ND	1	0.15	mg/Kg	9/22/98 MT
Chromium	ND	1	0.17	mg/Kg	9/22/98 MT
Copper	0.539	1	0.11	mg/Kg	9/22/98 MT
Lead	ND	1	0.40	mg/Kg	9/22/98 MT
Nickel	ND	1	0.20	mg/Kg	9/22/98 MT
Selenium	0.510	1	0.27	mg/Kg	9/22/98 MT
Silver	ND	1	0.50	mg/Kg	9/22/98 MT
Thallium	ND	1	0.40	mg/Kg	9/22/98 MT
Zinc	8.66	1	0.30	mg/Kg	9/22/98 MT
8080 - Chlorinated Pesticides and PCB's					
Aldrin	ND	1	0.002	mg/Kg	9/22/98 LS
Alpha BHC	ND	1	0.002	mg/Kg	9/22/98 LS
Beta BHC	ND	1	0.003	mg/Kg	9/22/98 LS
Chlordane	ND	1	0.008	mg/Kg	9/22/98 LS
DDD	ND	1	0.004	mg/Kg	9/22/98 LS
DDE	ND	1	0.003	mg/Kg	9/22/98 LS
DDT	ND	1	0.003	mg/Kg	9/22/98 LS
Delta BHC	ND	1	0.005	mg/Kg	9/22/98 LS
Dieldrin	ND	1	0.003	mg/Kg	9/22/98 LS
Endosulfan I	ND	1	0.004	mg/Kg	9/22/98 LS
Endosulfan II	ND	1	0.003	mg/Kg	9/22/98 LS
Endosulfan sulfate	ND	1	0.003	mg/Kg	9/22/98 LS
Endrin	ND	1	0.004	mg/Kg	9/22/98 LS
Endrin aldehyde	ND	1	0.004	mg/Kg	9/22/98 LS
Gamma BHC (Lindane)	ND	1	0.011	mg/Kg	9/22/98 LS
Heptachlor	ND	1	0.002	mg/Kg	9/22/98 LS

DLR = Detection limit for reporting purposes, ND = Not Detected below indicated detection limit, DF = Dilution Factor

Matrix: SOLID
Date Sampled: 9/3/98
Time Sampled:
Sampled By:

Client Sample ID: Jar 5
Sample Description: Ala Moana

Analyte	Result	DF	DLR	Units	Date/Analyst
8080 - Chlorinated Pesticides and PCB's					
Heptachlor epoxide	ND	1	0.003	mg/Kg	9/22/98 LS
Kepone	ND	1	0.01	mg/Kg	9/22/98 LS
Methoxychlor	ND	1	0.025	mg/Kg	9/22/98 LS
Mirex	ND	1	0.012	mg/Kg	9/22/98 LS
PCB-1016	ND	1	0.033	mg/Kg	9/22/98 LS
PCB-1221	ND	1	0.05	mg/Kg	9/22/98 LS
PCB-1232	ND	1	0.04	mg/Kg	9/22/98 LS
PCB-1242	ND	1	0.02	mg/Kg	9/22/98 LS
PCB-1248	ND	1	0.08	mg/Kg	9/22/98 LS
PCB-1254	ND	1	0.011	mg/Kg	9/22/98 LS
PCB-1260	ND	1	0.025	mg/Kg	9/22/98 LS
Toxaphene	ND	1	0.24	mg/Kg	9/22/98 LS

DLR = Detection limit for reporting purposes, ND = Not Detected below indicated detection limit, DF = Dilution Factor

Matrix: SOLID
Date Sampled: 9/3/98
Time Sampled:
Sampled By:
Client Sample ID: Jar 6
Sample Description: Ala Moana

Analyte	Result	DF	DLR	Units	Date/Analyst
245.5 Mercury in Solids by Manual Cold Vapor					
Mercury	0.17	1	0.12	mg/Kg	9/23/98 NK
335.2 Total Cyanide					
Cyanide	ND	1	0.5	mg/Kg	9/22/98 JA
6010 ICP Metals - Solid/Liquid					
Antimony	1.69	1	1.42	mg/Kg	9/22/98 MT
Arsenic	0.618	1	0.20	mg/Kg	9/22/98 MT
Beryllium	ND	1	0.10	mg/Kg	9/22/98 MT
Cadmium	ND	1	0.15	mg/Kg	9/22/98 MT
Chromium	9.98	1	0.17	mg/Kg	9/22/98 MT
Copper	0.745	1	0.11	mg/Kg	9/22/98 MT
Lead	ND	1	0.40	mg/Kg	9/22/98 MT
Nickel	0.491	1	0.20	mg/Kg	9/22/98 MT
Selenium	ND	1	0.40	mg/Kg	9/22/98 MT
Silver	ND	1	0.50	mg/Kg	9/22/98 MT
Thallium	ND	1	0.40	mg/Kg	9/22/98 MT
Zinc	3.84	1	0.30	mg/Kg	9/22/98 MT
8080 - Chlorinated Pesticides and PCB's					
Aldrin	ND	1	0.002	mg/Kg	9/23/98 LS
Alpha BHC	ND	1	0.002	mg/Kg	9/23/98 LS
Beta BHC	ND	1	0.003	mg/Kg	9/23/98 LS
Chlordane	ND	1	0.008	mg/Kg	9/23/98 LS
DDD	ND	1	0.004	mg/Kg	9/23/98 LS
DDE	ND	1	0.003	mg/Kg	9/23/98 LS
DDT	ND	1	0.003	mg/Kg	9/23/98 LS
Delta BHC	ND	1	0.005	mg/Kg	9/23/98 LS
Dieldrin	ND	1	0.003	mg/Kg	9/23/98 LS
Endosulfan I	ND	1	0.004	mg/Kg	9/23/98 LS
Endosulfan II	ND	1	0.003	mg/Kg	9/23/98 LS
Endosulfan sulfate	ND	1	0.003	mg/Kg	9/23/98 LS
Endrin	ND	1	0.004	mg/Kg	9/23/98 LS
Endrin aldehyde	ND	1	0.004	mg/Kg	9/23/98 LS
Gamma BHC (Lindane)	ND	1	0.011	mg/Kg	9/23/98 LS
Heptachlor	ND	1	0.002	mg/Kg	9/23/98 LS

DLR = Detection limit for reporting purposes, ND = Not Detected below indicated detection limit, DF = Dilution Factor

Matrix: SOLID
Date Sampled: 9/3/98
Time Sampled:
Sampled By:
Client Sample ID: Jar 6
Sample Description: Ala Moana

Analyte	Result	DF	DLR	Units	Date/Analyst
8080 - Chlorinated Pesticides and PCB's					
Heptachlor epoxide	ND	1	0.003	mg/Kg	9/23/98 LS
Kepone	ND	1	0.01	mg/Kg	9/23/98 LS
Methoxychlor	ND	1	0.025	mg/Kg	9/23/98 LS
Mirex	ND	1	0.012	mg/Kg	9/23/98 LS
PCB-1016	ND	1	0.033	mg/Kg	9/23/98 LS
PCB-1221	ND	1	0.05	mg/Kg	9/23/98 LS
PCB-1232	ND	1	0.04	mg/Kg	9/23/98 LS
PCB-1242	ND	1	0.02	mg/Kg	9/23/98 LS
PCB-1248	ND	1	0.08	mg/Kg	9/23/98 LS
PCB-1254	ND	1	0.011	mg/Kg	9/23/98 LS
PCB-1260	ND	1	0.025	mg/Kg	9/23/98 LS
Toxaphene	ND	1	0.24	mg/Kg	9/23/98 LS

DLR = Detection limit for reporting purposes, ND = Not Detected below indicated detection limit, DF = Dilution Factor